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FEATURES

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Foreword

James Irvine, Editor

This issue of the VTS News is a little unusual in that the mobile radio feature articles are two complementary articles giving more comprehensive coverage of a significant topic, in this case OFDM. The first part offers an introduction to OFDM and its history, and is of the normal tutorial nature the VTS News currently publishes. The second takes a more detailed look at the performance of OFDM in comparison to other systems, and is more in-depth than our usual articles. The articles also feature a very comprehensive list of references covering OFDM, its development and history.

Tutorial articles are popular, but there is currently a gap between the overview articles we publish and the highly academic papers published in the Transactions on Vehicular Technology. Feedback from members is that the Society should be doing more in the area of relevant information for practising engineers. The Board has committed more resources to the VTS News in 2005 to allow for enhanced content, particularly for graphical work, which allows us to tackle more complex articles than before. I would welcome your feedback on the types of article we should be soliciting.

The most significant change which will affect this publication is the planned transition to a magazine, which will hopefully take place from 2006. A magazine format will allow us to publish more articles, with some 30% more pages, as well as making our content more accessible through media such as IEEE Xplore™. While it will be significant cost to the Society, it is one that it can afford, and one that will improve the value of membership in the Society. In an increasingly electronic age, there is still a need for quality publications to distil the vast quantities of information our technical area develops, as well as to report and explain developments in the field.

The overall aim is to build on the strengths of the VTS News, retaining its columns on industry developments and overview articles accessible to members of all technical areas, and to enhance this with more specialist articles of a practical nature. 2005 will see changes to the administrative structure of the newsletter to match the new content. We would like to see more membership involvement in the process, so if you have ideas on what you would like to see in the expanded content, or would like to get involved in helping run the VTS News, or simply want to know more about what is planned, please get in touch with me at the address overleaf.

Copy for upcoming issues of *VTS News* should reach Dr. James Irvine by:

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A Stroll along Multi-carrier Boulevard to Next-Generation Plaza (I)—OFDM Background and History

Lajos Hanzo, Byoung-Jo Choi, and Matthias Münster, School of ECS, University of Southampton

In this introductory part of a two part series of articles on multi-carrier techniques, a background to Orthogonal Frequency Division Multiplex (OFDM) is provided, complemented by a detailed historical perspective of multi-carrier systems, identifying their most critical design aspects. These systems exhibit numerous attractive features, rendering them eminently eligible for employment in next-generation wireless systems. It is argued that symbol-by-symbol adaptive Orthogonal Frequency Division Multiplex (OFDM) modems counteract the near instantaneous channel quality variations and hence attain an increased throughput in comparison to their fixed-mode counterparts. By contrast, various diversity techniques, such as Rake receivers and space-time coding, mitigate the channel quality variations in their effort to obtain a reduced BER.

Motivation

Although the roll-out of the third-generation (3G) systems [1] has been somewhat delayed, the research community turned its attention to the investigation of next-generation multi-carrier transceiver techniques [2, 3, 4]. The next-generation wireless systems are expected to support both variable-rate as well as extremely high bitrate services in a wide range of different propagation environments. Under these propagation conditions it is unrealistic to expect that conventional fixed-mode transceivers might be capable of supporting a time-invariant wireline-like quality of service and hence near-instantaneously adaptive transceiver techniques [5, 6] have found their way into the High-Speed Downlink Packet Access (HSDPA) mode of the 3G systems. Multi-standard operation is also a salient requirement. As it was argued in the context of the generic futureproof system design framework outlined in Chapter 1 of [2], Multi-Carrier (MC) transmission techniques [2, 3, 7], such as Orthogonal Frequency Division Multiplexing (OFDM) [3] and its frequency domain spreading aided version, namely MC Code Division Multiple Access (MC-CDMA) exhibit the highest number of reconfigurable parameters amongst all potential transceivers schemes that may be reconfigured in an effort to satisfy the aforementioned challenging system requirements. Another attractive relative of this MC transceiver family is constituted by Direct Sequence (DS) MC-CDMA as well as its time-, frequency- and space-time-spreading assisted relatives [2, 8, 9]. Since DS MC-CDMA was documented in [2, 8, 9], following a rudimentary introduction to the subject and a brief tour of the MC transceiver history, this overview article will consider a number of design aspects pertaining to OFDM and frequency-domain spreading aided MC communications.

OFDM Basics

In this introductory section we examine OFDM as a means of counteracting the channel-induced linear distortions encountered, when transmitting over a dispersive radio channel. The fundamental principle of orthogonal multiplexing originates from Chang [10], and over the years a number of researchers have investigated this technique [11–22]. Despite its conceptual elegance, until recently its employment has been mostly limited to military applications due to implementational difficulties. However, it has recently been adopted as the new European Digital Audio Broadcasting (DAB) standard, and this consumer electronics application underlines its significance as a broadcasting technique [23–27].

In the OFDM scheme of Figure 1, the serial data stream of a channel is passed through a serial-to-parallel converter, which splits the data into a number of parallel channels. The data in each channel is applied to a modulator, such that for n channels there are n modulators whose carrier frequencies are $f_0, f_1, ..., f_{n-1}$. The frequency difference between adjacent channels is Δf and the overall bandwidth w of the N modulated subcarriers is $n\Delta f$.

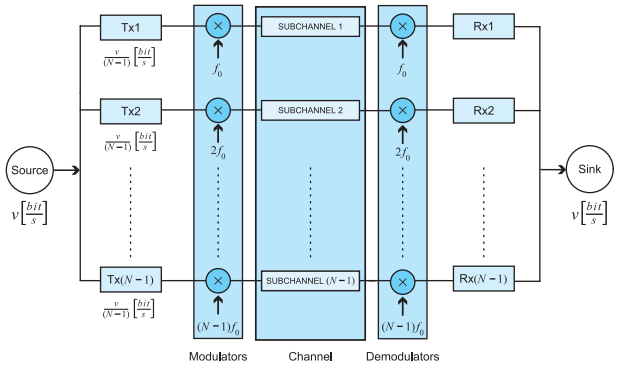

Figure 1 Simplified block diagram of the orthogonal parallel modem

These n modulated carriers are then combined to give an OFDM signal. We may view the serial-to-parallel converter as applying every nth symbol to a modulator. This has the effect of interleaving the symbols entered into each modulator, e.g. symbols S_0, S_n, S_{2n}, ... are applied to the modulator whose carrier frequency is f_1. At the receiver the received OFDM signal is demultiplexed into n frequency bands, and the n modulated signals are demodulated. The baseband signals are then recombined using a parallel-to-serial converter. The plausible benefit of expanding the duration of each subcarrier symbol is that at a given maximum channel-induced dispersion the relative fraction of a subcarrier symbol that is contaminated by dispersion is reduced by a factor of n.

In the more conventional serial transmission approach [4], the data is applied directly to the modulator transmitting at a carrier frequency positioned at the centre of the transmission band. The modulated signal occupies the entire bandwidth w. When the data is transmitted serially, a deep fade imposed by a mobile channel inflicts a burst of transmission errors, when the fade extends over the duration of several bits. By contrast, during an n-symbol transmission burst of the conventional serial system, each of the n number of OFDM subchannel modulators carries only one symbol, each of which has an n times longer duration. Hence, again, a fixed duration channel fade would only affect a fraction of the duration of each of the extended-length subcarrier symbols transmitted in parallel. Therefore the OFDM system may be able to recover all of the partially fading-contaminated n subcarrier symbols without transmission errors. Thus, while the serial system exhibits an error burst, no errors or only few errors may occur using the OFDM approach.

A further advantage of OFDM is that because the symbol period has been increased, the channel's delay spread becomes a significantly shorter fraction of an OFDM symbol period than in the serial system, potentially rendering the system less sensitive to channel-induced dispersion, than the conventional serial system.

A disadvantage of the OFDM approach portrayed in Figure 1 is its increased complexity in comparison to a conventional serial modem, which is a consequence of employing n subcarrier modulators and transmit filters at the transmitter as well as n demodulators and receive filters at the receiver.

However, as it was shown in Chapter 2 of [3], the associated complexity can be substantially reduced by employing the Discrete Fourier Transform (DFT) for modulating all subcarriers in a single step. From a tangible physical perspective this may be explained by arguing that all the OFDM subcarriers are orthogonal complex-valued exponential functions, which have a frequency that is an integer multiple of the basis frequency f_0, exactly as in case of the complex-valued exponential basis functions of the DFT/IDFT. Hence instead of multiplying each subcarrier individually for example by ±1 as in BPSK modulation, the modulation process implies 'transforming' a block of n BPSK modulated subcarrier symbols in a single step using the IDFT/DFT, yielding a block of n modulated samples, as illustrated mathematically in [3].

When the number of subcarriers is high, the system's complexity may be further reduced by implementing the DFT with the aid of the Fast Fourier transform (FFT), again, as it was shown mathematically in [3].

Adaptive OFDM Basics

As mentioned above, a particularly attractive feature of OFDM systems is that they are capable of operating without a classic channel equaliser, when communicating over dispersive transmission media, such as wireless channels, while conveniently accommodating the time- and frequency-domain channel quality fluctuations of the wireless channel.

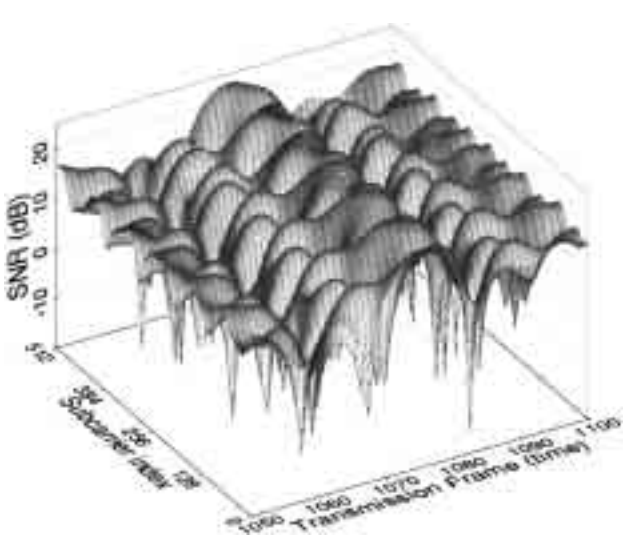

Figure 2 Instantaneous channel SNR for the 512 OFDM subcarriers versus time, for an average channel SNR of 16 dB over the channel characterised by the Channel Impulse Response (CIR) of Figure 3

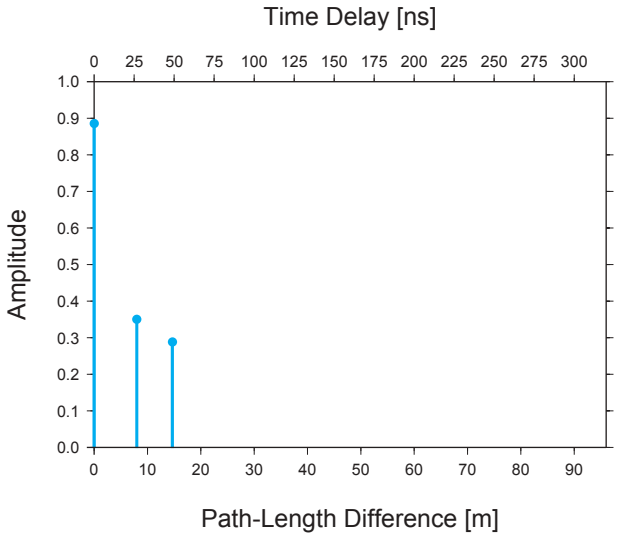

Figure 3 Indoor three-path Wireless Asynchronous Transfer Mode (WATM) CIR.

Explicitly, the channel SNR variation versus both time and frequency of an indoor wireless channel is shown in a three-dimensional form in Figure 2 versus both time and frequency, which suggests that OFDM constitutes a convenient framework for accommodating the channel quality fluctuations of the wireless channel, as will be briefly augmented below. This channel transfer function was recorded for the

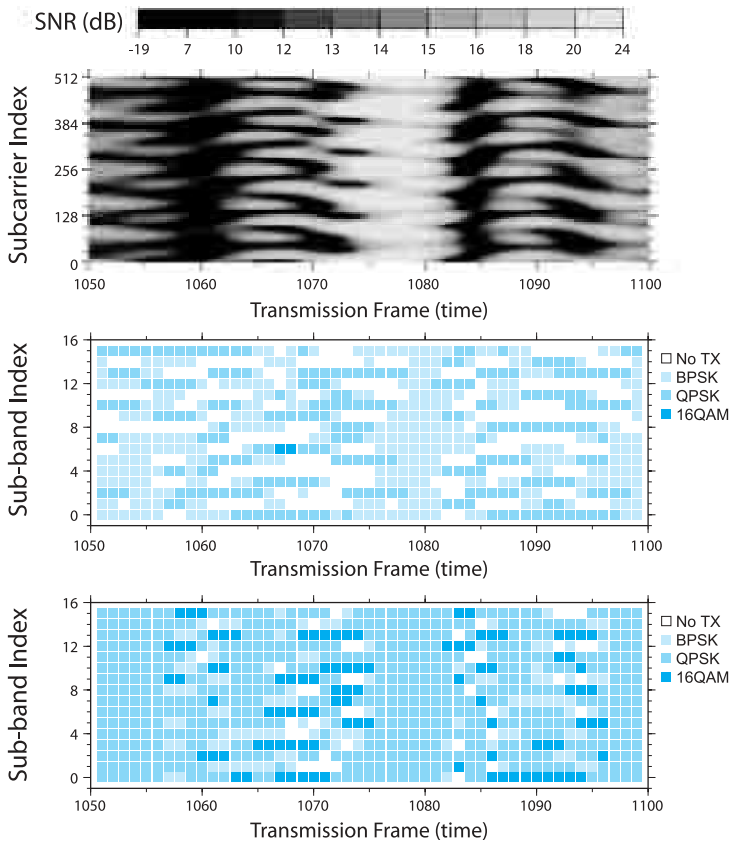

Figure 4 The micro-adaptive nature of the sub-band-adaptive OFDM modem. The top graph is a contour plot of the channel SNR for all 512 subcarriers versus time. The bottom two graphs show the modulation modes chosen for all 16 32-subcarrier subbands for the same period of time. The middle graph shows the performance of the 3.4 Mbps sub-band-adaptive modem, which operates at the same bit rate as a fixed BPSK modem. The bottom graph represents the 7.0 Mbps sub-band-adaptive modem, which operated at the same bit rate as a fixed QPSK modem. The average channel SNR was 16 dB

channel impulse response of Figure 3, by simply transforming the impulse response to the frequency domain at regular time intervals, while its taps fluctuated according to the Rayleigh distribution.

These channel quality fluctuations may be readily accommodated with the aid of sub-band-adaptive modulation as follows. Such an adaptive OFDM (AOFDM) modem is characterised by Figure 4, portraying at the top a contour plot of the aforementioned wireless channel's signal-to-noise ratio (SNR) fluctuation versus both time and frequency for each OFDM subcarrier. We note at this early stage that these channel quality fluctuations may be mitigated with the aid of frequency-domain channel equalisation, as it was illustrated both graphically as well as mathematically in [3]. We will briefly revisit this topic also in this contribution at a later stage.

More specifically, as seen in Figures 2 and 4, when the channel is of high quality—as for example in the vicinity of the OFDM symbol index of 1080—a higher throughout may be achieved, than during the periods of lower channel quality. The average throughput of each OFDM symbol constituted by a column of 16 stacked 32-subcarrier subbands was 1 bit per symbol (BPS) in this example, as in conventional Binary Phase Shift Keying (BPSK).

More explicitly, in the centre and bottom subfigures of Figure 4 the modulation mode chosen for each 32-subcarrier sub-band is shown versus time for two different high-speed wireless modems communicating at either 3.4 or 7.0 Mbps, respectively, again, corresponding to an average throughput of either 1 or 2 BPS.

However, these adaptive transceiver principles are not limited to employment in OFDM transmissions. In recent years the concept of intelligent multi-mode, multimedia transceivers (IMMT) has emerged in the context of a variety of wireless systems [2, 4, 5, 28–32]. The range of various existing solutions that have found favour in already operational standard systems has been summarised in the excellent overview by Nanda *et al* [31].

The aim of these adaptive transceivers is to provide mobile users with the best possible compromise amongst a number of contradicting design factors, such as the power consumption of the handheld portable station (PS), robustness against transmission errors, spectral efficiency, teletraffic capacity, audio/video quality, and so forth [30].

Another design alternative applicable in the context of OFDM systems is that the channel quality fluctuations observed, for example, in Figure 2 are averaged out with the aid of frequency-domain spreading codes, which leads to the concept of frequency-domain spreading aided MC-CDMA [3]. In this scenario typically only a few chips of the spreading code are obliterated by the frequency-selective fading, hence the chances are that the spreading code and its conveyed subcarrier data symbol may still be recoverable. The advantage of this approach is that in contrast to AOFDM-based communications, in MC-CDMA no channel quality estimation and signalling are required. Therefore, based on the more detailed exposures in [3], OFDM and MC-CDMA will be comparatively studied in the Uncoded Adaptive System, Turbo-Coded Fixed Modem, and Turbo Coded Adaptive System sections of this contribution. We will also consider the employment of Walsh-Hadamard code-based spreading of each subcarrier's signal across the entire OFDM bandwidth, which was found to be an efficient frequency-domain fading counter-measure capable of operating without the employment of adaptive modulation [5].

A further technique capable of mitigating the channel quality fluctuations of wireless channels is constituted by space-time coding [6], which will also be considered as an attractive anti-fading design option capable of attaining a high diversity gain. Space-time coding employs several transmit and receive antennas for the sake of achieving diversity gain and hence results in an improved performance.

By contrast, in Part 2 of [3] multiple antennas were employed at the base-station for a different reason, namely for the sake of supporting multiple users, rather than for achieving transmit diversity gain. This is possible, since the users' channel impulse responses (CIR) or channel transfer functions are accurately estimated and hence these channel transfer functions may be viewed as unique user-specific

signature sequences, which allow us to both recognise and to demultiplex the simultaneous transmissions of the individual users, in a similar fashion to the unique user-specific spreading codes employed in CDMA systems. We note, however, that this technique is only capable of reliably separating the users communicating within the same bandwidth, if their CIRs are sufficiently different. This assumption is typically valid for the uplink, although it may have a limited validity, when the base station receives from mobile stations having a similar CIR in its immediate vicinity. By contrast, different techniques have to be invoked for downlink multi-user transmissions. For reasons of space economy, here we restrict our discourse on SDMA schemes to a rudimentary discussion of the related research aspects in the Decision-Directed Channel Estimation and Uplink Detection Techniques for Multi-User SDMA-OFDM sections.

Having reviewed some of the basic OFDM-related transceiver functions, let us now provide a historical perspective embedded in to a rudimentary overview of the more specific system design aspects in the next section.

Orthogonal Frequency Division Multiplexing History

Early Classic Contributions

The first OFDM scheme was proposed by Chang in 1966 [10] for inter-symbol interference-free (ISI) transmissions over dispersive fading channels. During the early years of the evolution of OFDM research various contributions due to the efforts of Weinstein, Peled, Ruiz, Hirosaki, Kolb, Cimini, Schüssler, Preuss, Rückriem, Kalet *et al* [10, 11, 15, 20, 25, 26, 16, 17, 18, 19, 21, 22, 27, 33] have to be mentioned. As unquestionable proof of its maturity, OFDM was standardised as the European DAB as well as Digital Video Broadcast (DVB) scheme. It constituted also a credible proposal for the recent third-generation mobile radio standard competition in Europe. Finally, OFDM was also selected as the European High Performance Local Area Network's (HIPERLAN) transmission technique as well as part of the IEEE 802.11 Wireless Local Area Network (WLAN) standard.

As it was portrayed in Figure 1, the system's operational principle is that the original bandwidth is divided into a high number of narrow sub-bands, in which the mobile channel can be considered non-dispersive. Hence no channel equaliser is required and instead of implementing a bank of sub-channel modems, they can be conveniently implemented with the aid of a single FFT operation by transforming or modulating a block of n subcarrier symbols in a single step, as was shown mathematically in Chapter 2 of [3].

These OFDM systems—often also termed frequency division multiplexing (FDM) or multi-tone systems—have been employed in military applications since the 1960s, for example by Bello [34], Zimmermann [11], Powers and Zimmerman [12], Chang and Gibby [14] and others. Saltzberg [13] studied a multi-carrier system employing orthogonal time-staggered quadrature amplitude modulation (O-QAM) of the carriers.

The employment of the DFT for replacing the banks of sinusoidal modulators and demodulators was suggested by Weinstein and Ebert [15] in 1971, which significantly reduces the implementation complexity of OFDM modems. In 1980, Hirosaki [33] suggested an equalisation algorithm in order to suppress both intersymbol and intersubcarrier interference caused by the channel impulse response or by timing and frequency errors. Simplified OFDM modem implementations were studied by Peled [16] in 1980, while Hirosaki [17] introduced the DFT-based implementation of Saltzberg's O-QAM OFDM system. From Erlangen University, Kolb [18], Schüssler [19], Preuss [21] and Rückriem [22] conducted further research into the application of OFDM. Cimini [20] and Kalet [27] published analytical and early seminal experimental results on the performance of OFDM modems in mobile communications channels. More recent advances in OFDM transmission were presented in the impressive state-of-the-art collection of works edited by Fazel and Fettweis [35], including the research by Fettweis *et al* at Dresden University, Rohling *et al* at University of Hong Kong, Vandendorp at Loeven University, Huber et al at Erlangen University, Lindner et al at Ulm University, Kammeyer *et al* at Bremen University and Meyr *et al* [36, 37] at Aachen University, but the individual contributions are too numerous to mention. Important recent references are the books by van Nee and Prasad [38] as well as by Vandenameele, van der Perre and Engels [39].

While OFDM transmission over mobile communications channels can alleviate the problem of multipath propagation, it is by no means flawless. Hence, recent research efforts have been focused on solving a set of inherent difficulties regarding OFDM, namely the peak-to-mean power ratio, time and frequency synchronisation, and on mitigating the effects of the frequency selective fading channel. These issues are addressed below with reference to the literature, while a more in-depth treatment is given throughout the book [3].

Peak-to-mean Power Ratio

It is plausible that the OFDM signal—which is the superposition of a high number of modulated sub-channel signals—may exhibit a high instantaneous signal peak with respect to the average signal level. Furthermore, large signal amplitude swings are encountered, when the time domain signal traverses from a low instantaneous power waveform to a high-power waveform, which may results in a high out-of-band (OOB) harmonic distortion power, unless the transmitter's power amplifier exhibits an extremely high linearity across the entire signal magnitude range. This then potentially contaminates the adjacent channels with adjacent channel interference. Practical amplifiers exhibit a finite amplitude range, in which they can be considered almost linear. In order to prevent severe clipping of the high OFDM signal peaks—which is the main source of OOB emissions—the power amplifier must not be driven to saturation and hence the amplifiers are typically operated with a certain so-called back-off, creating a certain "head room" for the signal peaks, which reduces the risk of amplifier saturation and OOB emission. Two different families of solutions have been suggested in the literature, in order to mitigate these problems, either reducing the peak-to-mean power ratio, or improving the amplification stage of the transmitter.

More explicitly, Shepherd [40], Jones [41], and Wulich [42] have suggested the employment of techniques which aim for minimising the peak power of the OFDM signal by employing different data encoding schemes before modulation. The philosophy of these data encoding schemes is that they employ specific block codes for encoding the modulating data symbols by concatenating appropriate redundant symbols, which mitigate the associated peak of the modulated signal. In other words, the legitimate crest-factor reduction code words exhibit low crest factors or peak-to-

mean power envelope fluctuation. Müller [43], Pauli [44], May [45] and Wulich [46] suggested different algorithms for post-processing the time domain OFDM signal prior to amplification, while Schmidt and Kammeyer [47] employed adaptive subcarrier allocation in the spirit of [3], where the allocation of modulating bits was also minimising the resultant crest factor. Dinis and Gusmao [48, 49, 50] researched the employment of two-branch amplifiers, where each amplifier was fed with a near-constant-envelope signal, while the clustered OFDM technique introduced by Daneshrad, Cimini and Carloni [51] employs a set of parallel partial FFT processors in conjunction with separate associated transmitting chains. OFDM systems with increased robustness to non-linear distortion have also been proposed by Okada, Nishijima and Komaki [52] as well as by Dinis and Gusmao [53]. These as well as range of other crest-factor related aspects of OFDM transmissions were treated in substantial depth in Part 2 of [3].

Synchronisation

Time and frequency synchronisation between the transmitter and receiver are of crucial importance as regards to the performance of an OFDM link [54, 55]. A wide variety of techniques have been proposed for estimating and correcting both timing and carrier frequency offsets at the OFDM receiver. Rough timing and frequency acquisition algorithms relying on known pilot symbols or pilot tones embedded into the OFDM symbols have been suggested for example by Classen [36], Warner [56], Sari [57], Moose [58], as well as by Brüninghaus and Rohling [59]. The philosophy of these pilot-based methods is that they allow the receiver to estimate the associated change of phase imposed by the channel as well as by the timing- and frequency-differences of the transmitter's and receiver's oscillators. Once the composite mis-adjustment has been estimated, it may also be readily compensated. Frequency and timing fine-tracking algorithms exploiting the OFDM signal's cyclic extension were published by Moose [58], Daffara [60] and Sandell [61], where it was exploited that the phase-change across the OFDM symbol's duration imposed by the time-delay alone is know. If the actual phase difference deviates from the expected difference, this may be deemed to be the consequence of oscillator frequency- or phase errors and hence may be compensated. A range of OFDM synchronisation issues constitutes the subject of Chapter 5 in [3].

Hybrid OFDM, CDMA and MC-CDMA Systems

Combining multi-carrier OFDM transmissions with Code Division Multiple Access (CDMA) allows us to exploit the wideband channel's inherent frequency diversity by spreading each subcarrier's modulating symbol across multiple subcarriers. As mentioned before, the attraction of this operation is that even if a subcarrier and the corresponding chip of the spreading code mapped to it is obliterated, the spreading code and the corresponding original unspread symbol may still be recoverable. Furthermore, upon using unique user-specific spreading codes the system is also capable of supporting multiple users. This technique has been pioneered by Yee, Linnartz and Fettweis [62]; by Chouly, Brajal and Jourdan [63]; as well as by Fettweis, Bahai and Anvari [64]. Fazel and Papke [65] investigated convolutional coding in conjunction with OFDM/CDMA. Prasad and Hara [66] compared various methods of combining the two techniques, identifying three different structures, namely MC-CDMA [3], Multi-carrier Direct Sequence CDMA (MC-DSCDMA) [3] and Multi-tone CDMA (MT-CDMA). Like classic unspread OFDM transmission, the various OFDM/CDMA methods also suffer from high peak-to-mean power ratios, which are dependent on the specific choice of the specific frequency domain spreading scheme employed, as investigated by Choi, Kuan and Hanzo [67] and in Part 2 of [3].

Pilot-Aided Channel Estimation

The effects of the transmission channel manifest themselves in that the transmitted OFDM signal is convolved with the CIR, or when interpreted in the frequency-domain, it is multiplied by the frequency-domain channel transfer function (FDCHTF). At the receiver these channel-induced linear distortions have to be removed, which is typically carried out by estimating the FDCHTF and then multiplying the received signal with the inverse of the FDCHTF.

In recent years numerous research contributions have appeared on the topic of channel transfer function estimation techniques designed for employment in single-user, single transmit antenna-assisted OFDM scenarios, since the availability of an accurate channel transfer function estimate is one of the prerequisites for coherent symbol detection with an OFDM receiver. The techniques proposed in the literature can be classified as pilot-assisted, decision-directed (DD) and blind channel estimation (CE) methods.

The simple philosophy of pilot-assisted frequency-domain channel estimation is that known pilot-symbols are allocated to the OFDM subcarriers at regular frequency spacing. The pilot-spacing required for FDCHTF estimation is determined by the rate of FDCHTF fluctuation versus the frequency axis. More explicitly, these pilot subcarriers have to facilitate adequate sampling of the FDCHTF H(n), requiring that the corresponding sampling frequency is higher than the Nyquist frequency necessitated for the aliasing-free representation of the FDCHTF, as well as for its recovery from these pilot-aided "Nyquist-rate samples" of the FDCHTF [3]. The frequency-separation between the FDCHTF fades observed in Figure 2 depends on the maximum CIR duration observed for example in Figure 3, since the CIR duration and the frequency-domain spacing of the deep fades constitutes Fourier transform pairs. More explicitly, the longer the CIR, the more frequent are the FDCHTF fades and vice versa.

The aforementioned OFDM symbol-by-symbol based FDCHTF estimation approach may be rendered more efficient, potentially requiring a lower pilot overhead, if the FDCHTF of consecutive OFDM symbols is predicted also as a function of time, resulting in two-dimensional (2D) pilot-aided FDCHTF estimation, as detailed in [3]. As in the context of the FDCHTF estimation versus frequency, the required time-direction pilot-density is also determined by the Nyquist theorem, this time obeying twice the Doppler frequency encountered by the CIR taps, as it is illustrated both graphically as well as mathematically in [3]. The family of pilot-assisted channel estimation techniques was also investigated for example by Chang and Su [68], Höher [69–71], Itami *et al* [72], Li [73], Tufvesson and Maseng [74], Wang and Liu [75], as well as Yang *et al* [76–8]. Let us now briefly consider the family of Decision-Directed Channel Estimation (DDCE) schemes.

Decision-Directed Channel Estimation

By contrast, in the context of DDCE all the sliced and remodulated subcarrier data symbols are considered as pilots. Provided that there are no subcarrier decision errors, the performance of DDCE may approach that of the perfect channel estimation scenario. Phrased in more practical

terms, in the absence of subcarrier symbol errors and also depending on the Doppler frequency-related rate of channel fluctuation, it was found that accurate channel transfer function estimates can be obtained, which may be of better quality in terms of the channel transfer function estimator's mean-square error (MSE), than the estimates offered by pilot-assisted schemes. This is because the latter arrangements usually invoke relatively sparse pilot patterns.

More explicitly, the family of decision-directed channel estimation techniques was investigated for example by van de Beek *et al* [79], Edfors *et al* [80, 81], Li *et al* [82], Li [83], Mignone and Morello [84], Al-Susa and Ormondroyd [85], Frenger and Svensson [86], as well as Wilson *et al* [87]. Furthermore, the family of blind channel estimation techniques using no channel sounding pilots was studied by Lu and Wang [88], Necker and Stüber [89], as well as by Zhou and Giannakis [90].

In order to render the various DDCE techniques more amenable to employment in scenarios associated with a relatively high rate of FDCHTF variation expressed in terms of the OFDM symbol normalised Doppler frequency, linear prediction techniques well known from the speech coding literature [91, 92] can be invoked. To elaborate a little further, every FDCHTF sample may be predicted from a number of consecutive previous FDCHTF samples positioned at the specific subcarrier frequency considered. However, in case of, for example, 512 subcarriers, the same number of predictors would be required, which results in a high complexity. A computationally more efficient solution is to transform the FDCHTF to the time-domain, yielding the CIR. Since the CIR typically has only a low number of significant taps, their prediction is computationally less demanding, even, when taking into account the complexity of the IFFT/FFT operation required for generating the CIR and transforming it back to the frequency-domain [82]. The general concepts described by Duel-Hallen *et al* [93] and the ideas presented by Frenger and Svensson [86], where a frequency domain prediction filter-assisted DDCE was proposed, also contributed substantially to the literature of DDCE. Furthermore, we should mention the contributions of Tufvesson *et al* [94, 95], where a prediction filter-assisted frequency domain pre-equalisation scheme was discussed in the context of OFDM. In a further contribution by Al-Susa and Ormondroyd [85], adaptive prediction filter-assisted DDCE designed for OFDM has been proposed upon invoking techniques known from speech coding, such as the Levinson-Durbin algorithm or the Burg algorithm [91, 96, 97] in order to determine the DDCE's predictor coefficients.

Uplink Detection Techniques for Multi-user SDMA-OFDM

Combining adaptive antenna-aided techniques with OFDM transmissions was shown to be advantageous [3], for example in the context of suppressing co-channel interference in cellular communications systems. Amongst others, Li, Cimini and Sollenberger [98, 99, 100], Kim, Choi and Cho [101], Lin, Cimini and Chuang [102] as well as Münster *et al* [103] have investigated algorithms designed for multi-user channel estimation and interference suppression.

The related family of Space-Division-Multiple-Access (SDMA) communication systems has recently drawn wide research interests [3]. In these systems the L different users' transmitted signals are separated at the Base-Station (BS) with the aid of their unique, user-specific spatial signature, which is constituted by the P-element vector of channel transfer factors between the users' single transmit antenna and the P different receiver antenna elements at the BS, upon assuming flat-fading channel conditions such as those often experienced in the context of each of the OFDM subcarriers. A whole host of Multi-user Detection (MUD) techniques known from the literature of CDMA communications lend themselves also to employment in the context of SDMA-OFDM on a per-subcarrier basis [3]. Some of these techniques are the Least-Squares (LS) [104–7], Minimum Mean-Square Error (MMSE) [104, 105, 108–116], Successive Interference Cancellation (SIC) [104–6, 111, 115, 117–121], Parallel Interference Cancellation (PIC) [104, 122], and Maximum Likelihood (ML) MUD arrangements [104, 111, 115, 123–9].

Channel Estimation for Multi-user SDMA-OFDM

In contrast to the aforementioned single-user OFDM scenarios, in a multi-user OFDM scenario the signal received by each antenna is constituted by the superposition of the signal contributions associated with the different users or transmit antennas. Note that in terms of the multiple-input multiple-output (MIMO) structure of the channel the multi-user single-transmit antenna scenario is equivalent; for example, to a single-user space-time coded (STC) scenario by using multiple transmit antennas. For the latter a Least-Squares (LS) error channel estimator was proposed by Li *et al* [130], which aims at recovering the different transmit antennas' channel transfer functions on the basis of the output signal of a specific reception antenna element and by also capitalising on the remodulated received symbols associated with the different users. The performance of this estimator was found to be limited in terms of the mean-square estimation error in scenarios where the product of the number of transmit antennas and the number of CIR taps to be estimated per transmit antenna approached the total number of subcarriers hosted by an OFDM symbol. As a design alternative, in [131] a DDCE was proposed by Jeon *et al* for a space-time coded OFDM scenario of two transmit antennas and two receive antennas.

Specifically, the channel transfer function[1] associated with each transmit-receive antenna pair was estimated on the basis of the output signal of the specific receive antenna upon subtracting the interfering signal contributions associated with the remaining transmit antennas. These interference contributions were estimated by capitalising on the knowledge of the channel transfer functions of all interfering transmit antennas predicted during the $(n-1)$-th OFDM symbol period for the n-th OFDM symbol, also invoking the corresponding remodulated symbols associated with the n-th OFDM symbol. To elaborate further, the difference between the subtraction-based channel transfer function estimator of [131] and the LS estimator proposed by Li et al in [130] is that in the former the channel transfer functions predicted during the previous, i.e. the $(n-1)$-th OFDM symbol period for the current, i.e. the n-th OFDM symbol are employed for both symbol detection as well as for obtaining an updated channel estimate for employment during the (n + 1)-th OFDM symbol period. In the approach advocated in [131] the subtraction of the different transmit antennas' interfering signals is performed in the frequency domain.

By contrast, in [132] a similar technique was proposed by Li with the aim of simplifying the DDCE approach of [130], which operates in the time domain. A prerequisite for the operation of this parallel interference cancellation (PIC)-assisted DDCE is the availability of a reliable estimate of the

[1] In the context of the OFDM system the set of K different subcarriers* channel transfer factors is referred to as the channel transfer function, or simply as the channel.

various channel transfer functions for the current OFDM symbol, which are employed in the cancellation process in order to obtain updated channel transfer function estimates for the demodulation of the next OFDM symbol. In order to compensate for the channel's variation as a function of the OFDM symbol index, linear prediction techniques can be employed, as it was also proposed for example in [132]. However, due to the estimator's recursive structure, determining the optimum predictor coefficients is not as straightforward as for the transversal FIR filter-assisted predictor of single-user DDCE, both of which are detailed in [3].

OFDM Applications

Owing to their relatively high implementational complexity and crest-factor problems, OFDM applications have been scarce until quite recently. During the late 1990s, however, OFDM has been adopted as the new European DAB standard [23–6, 133] as well as for the terrestrial DVB system [57, 134].

For fixed-wire applications, OFDM is employed in the Asynchronous Digital Subscriber Loop (ADSL) and High-bit-rate Digital Subscriber Loop (HDSL) [135–8] and it has also been suggested for employment in power line communications systems [139, 140] owing to its resilience to both time dispersive channels and narrow band interferers.

Various OFDM applications were also studied within the 4th-6th European Framework Programme [141]. For example, an OFDM-based 155 Mbps WATM network was designed by the so-called MEDIAN project in [142–5], while the MagicWAND research consortium [146, 147] developed a WLAN. Hallmann and Rohling [148] presented a range of different OFDM systems that were applicable to the European Telecommunications Standardisation Institute's (ETSI) recent personal communications oriented air interface concept [149].

Conclusion

This first article has provided a historical perspective of OFDM/MC-CDMA multicarrier systems, identifying their most critical design aspects. These systems exhibit numerous attractive features, rendering them eminently eligible for employment in next-generation wireless systems.The following article will now focus on an OFDM/MCCDMA system design study, in an effort to contribute towards the research of next-generation systems.

References

References for this article are combined with references for Part II, and can be found starting on Page 15.

Author biographies can be found on Page 17

A Stroll along Multi-carrier Boulevard to Next-Generation Plaza (II)—Space-Time Coded Adaptive OFDM & MC-CDMA Performance Comparison

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This companion article investigates a combined system constituted by a constant power adaptive modem employing space-time coded diversity techniques in the context of both OFDM and MC-CDMA. The combined system is configured to produce a constant uncoded BER and exhibits virtually error-free performance when a turbo convolutional code is concatenated with a space-time block code. It was found that the advantage of rendering the modem adaptive erodes when the affordable system complexity is less limited and hence the overall diversity-order may be increased.

Adaptive OFDM versus Multi-carrier CDMA

System Model and AOFDM Switching Levels

The family of OFDM-based multi-carrier systems [3, 4] approach the theoretically highest possible 2Bd/Hz bandwidth efficiency quantified by Shannon, since they typically require only a small raised-cosine excess bandwidth for Nyquist-filtering. Hence, they are considered attractive for downlink wireless Internet services in future fourth generation (4G) systems as well as in high-speed Wireless Local Area Networks (WLAN). However, OFDM in its basic form cannot fully benefit from the multi-path diversity potential of wideband channels.

It was reported in the literature that the synchronisation requirement of MC-CDMA is within 10% of the frame length [150]. Thus, an MC-CDMA system having the appropriate modem parameters constitutes an attractive downlink multiple access scheme for both fixed and slowly moving mobile terminals, where maintaining near-synchronous operation is feasible. Since MC-CDMA facilitates diversity reception similarly to a Rake receiver, the performance of single-user MC-CDMA is characterised by that of an ideal Rake receiver. In a multi-user scenario joint-detection assisted MC-CDMA employing

the MMSE-BDFE [151] receiver approaches the single-user performance.

When channel coding is employed in conjunction with frequency domain interleaving, OFDM substantially benefits from the frequency domain diversity. However, OFDM may not be capable of exploiting the diversity potential of the channel to the same extent as MC-CDMA, since in OFDM the channel error statistics are more bursty than in MC-CDMA. Hence, it is interesting to compare the coded BERs of OFDM and MMSE-BDFE aided MC-CDMA in conjunction with concatenated turbo codes and space-time block codes over wideband Rayleigh channels.

Various combinations of Space-Time (ST) codes and channel codes can be used for transmission over wideband fading channels [6, 152]. An attractive option is to use a half-rate turbo convolutional code concatenated to a space-time block code using two transmit antennas and to expand the signal constellation to a higher order modulation mode in order to match the throughput of the system using no channel coding. Another approach to maintaining a high effective throughput is to use a high-rate turbo BCH code in conjunction with a ST trellis code or ST block code and a lower order modulation mode, than in case of the half-rate FEC scheme. It was reported in [6, 152] that the former approach gives a lower BER, than the latter. Hence, we will employ a half-rate turbo convolutional code in our comparative study.

As argued in the context of Figure 2 in Part 1 (This issue, Page 4), wideband fading channels exhibit two-dimensional channel quality variations, namely both time domain variation and frequency domain variation, and OFDM lends itself to exploiting these two-dimensional channel quality variations [3, 153, 154]. In other words, both time- and frequency-domain adaptivity can be simultaneously exploited in OFDM. By contrast, although capable of providing frequency domain diversity with the aid of averaging the channel qualities of several subcarriers, MC-CDMA is less amenable to frequency domain adaptation, than to time domain adaptation.

In order to contribute towards the next-generation system studies, the aim of this second part is to compare the performances of space-time as well as turbo-coded adaptive OFDM and MC-CDMA modems. Although adaptive coded multi-carrier modulation systems have been extensively studied [153, 155, 156], the effect of transmit diversity has not been considered.

Figure 5 portrays the stylised transmitter structure of our prototype system. The source bits are channel coded by a half-rate turbo convolutional encoder [6, 157] using a constraint length of K = 3 as well as an interleaver size of L = 3072 bits and interleaved by a random block interleaver. Then, the AQAM block selects a modulation mode from the set of no

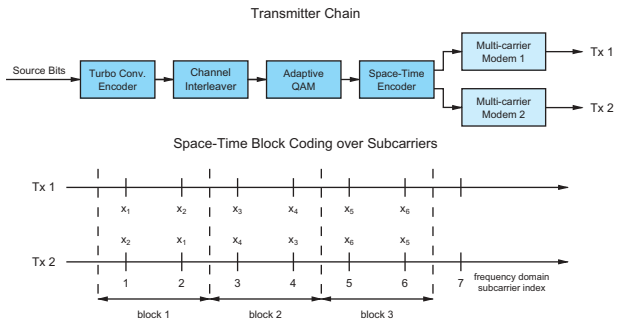


Figure 5 Transmitter structure and space-time block encoding scheme

transmission, BPSK, QPSK, 16-QAM and 64-QAM modes, depending on the instantaneous channel quality perceived by the receiver, according to the predetermined SNR-dependent switching thresholds. It is assumed that the perfectly estimated channel quality experienced by receiver A is fed back to transmitter B superimposed on the next burst transmitted to receiver B. The modulation mode switching levels of our AQAM scheme determine the average BER as well as the average throughput. A set of optimum switching thresholds was derived in [158] for transmission over flat Rayleigh fading channels. However, AQAM modems employing these switching thresholds inevitably exhibit a variable average BER across the SNR range, despite aiming for a given fixed target BER, namely Bt. In order to achieve a constant target BER, while maintaining the maximum possible throughput, a new set of SNR-dependent switching thresholds was devised for transmission over wideband channels [159, 160].

Figure 6 illustrates the switching levels optimised for both adaptive OFDM and adaptive MC-CDMA for the target BER of Bt = 10-3. The optimum switching levels decrease, as the average channel SNR increases and hence higher-throughput modulation modes can be invoked more frequently. Figure 6 also shows the "avalanche" SNR, beyond which adaptive mode switching is abandoned in favour of the fixed highest-order modulation mode, namely 64-QAM, since the BER of 64-QAM satisfies the target BER requirement. The modulated symbol is now space-time encoded. As seen at the bottom of Figure 5, Alamouti's space-time block code [161, 6] is applied across the frequency domain. A pair of the adjacent subcarriers belonging to the same space-time encoding block is assumed to have the same channel quality. We employed the WATM channel model of Figure 3 [4, p.476] transmitting at a carrier frequency of 60GHz, at a sampling rate of 225MHz and employing 512 subcarriers. Specifically, we used a 3-path fading channel model,

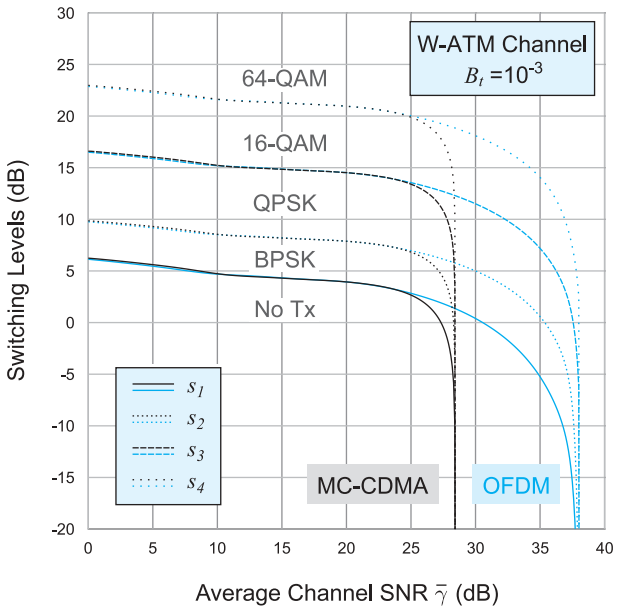
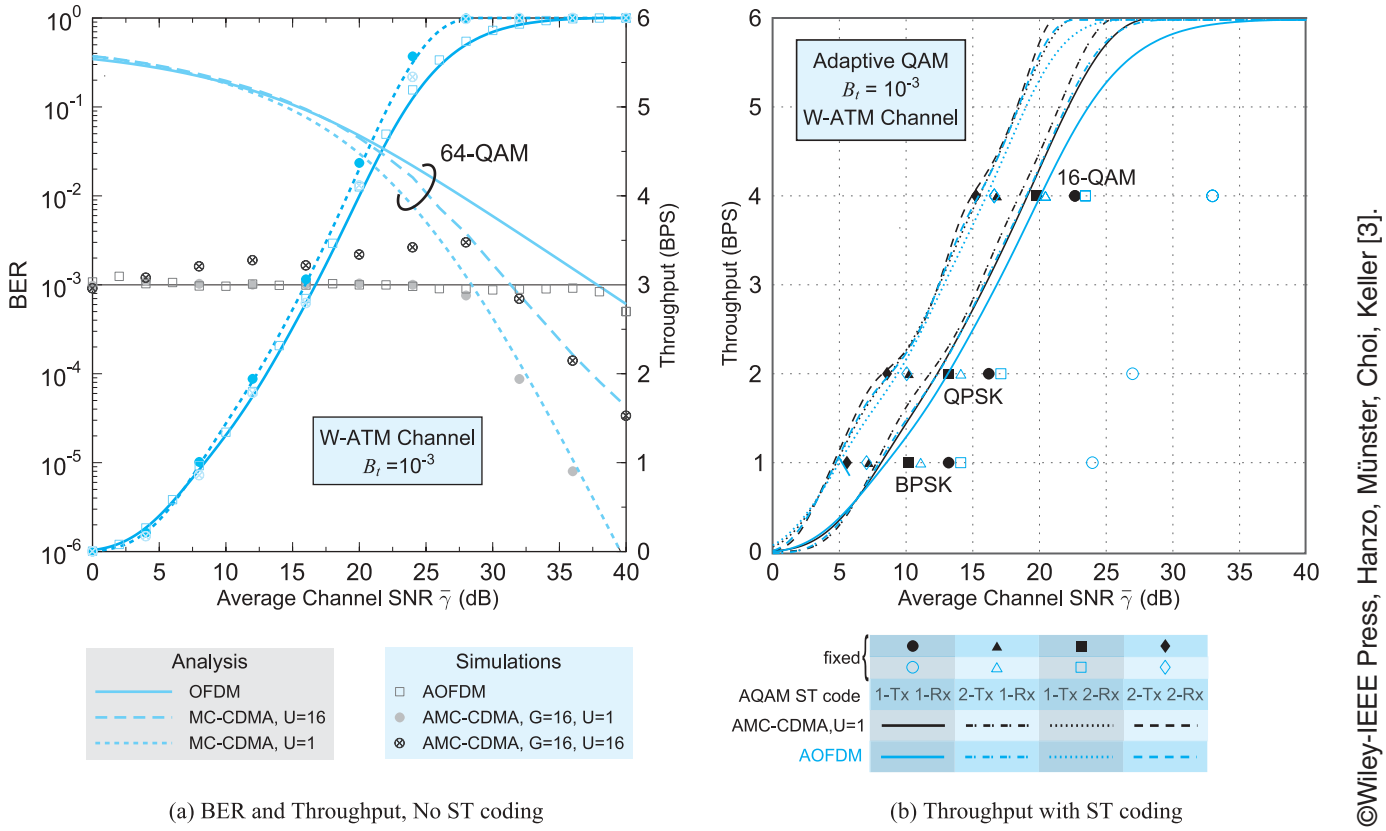


Figure 6 The optimum switching levels devised for the target BER of Bt = 10-3, when using 1 Tx antenna and 1 Rx antenna. The WATM channel model [4, p.476] is assumed for MC-CDMA. The switching levels for OFDM were obtained for narrow-band Rayleigh channels, which can be used for any multi-path profile, since OFDM renders the dispersive channel non-dispersive



(a) BER and Throughput, No ST coding

(b) Throughput with ST coding

Figure 7 Performance of uncoded five-mode AOFDM and AMC-CDMA. The target BER is Bt = 10^{-3} transmitting over the WATM channel [4, p.476]. (a) The constant average BER is maintained for AOFDM and single user AMC-CDMA, while "full-user" AMC-CDMA exhibits a slightly higher average BER due to the residual MUI. (b) The SNR gain of adaptive modems decreases as ST coding increases the diversity order. The BPS curves appear in pairs, corresponding to AOFDM and AMC-CDMA—indicated by the thin and thick lines, respectively—for each of the four different ST code configurations. The markers represent the SNRs required by the fixed-mode OFDM and MC-CDMA schemes for maintaining the target BER of 10^{-3} in conjunction with the four ST-coded schemes

where the average SNR of each path is given by, and each channel associated with a different pair of transmit and receive antennas was assumed to exhibit independent fading.

Uncoded Adaptive System

The simulation results characterising our uncoded adaptive modems are presented in Figure 7. Since we employed the optimum switching levels of Figure 6, both our adaptive OFDM (AOFDM) and the adaptive single-user MC-CDMA (AMC-CDMA) modems maintain the constant target BER of 10-3 up to the "avalanche" SNR value seen in Figure 6 and then follow the BER curve of the 64-QAM mode. However, "full-user" AMC-CDMA supporting U = 16 users with the aid of a spreading factor of G = 16 and employing the MMSE-BDFE Joint Detection (JD) receiver [151] exhibits a slightly higher average BER, than the target of Bt = 10-3 due to the residual Multi-User Interference (MUI) of the imperfect joint detector. Since we derived the optimum switching levels based on a single-user system, the switching levels are no longer optimum, when residual MUI is present. The average throughputs expressed in terms of Bits Per Symbol (BPS) steadily increase and reach the throughput of 64-QAM, namely 6 BPS. The throughput degradation of "full" user MC-CDMA in comparison to the single-user scenario was within a fraction of one dB. Observe in Figure 7(a) that the analytical and simulation results are in good agreement, which we denoted by the lines and distinct symbols, respectively.

The effects of ST coding on the average BPS throughput are displayed in Figure 7(b). Specifically, the thick lines represent the average BPS throughput of our AMC-CDMA scheme, while the thin lines represent those of our AOFDM modem. The four pairs of hollow and filled markers associated with four different ST-coded scenarios represent the BPS throughput versus SNR values associated with fixed-mode OFDM and fixed-mode MMSE-BDFE JD assisted MC-CDMA. Specifically, the right-most markers correspond to the 1-Tx / 1-Rx, the second to the 2-Tx / 1-Rx, the third to the 1-Tx / 2-Rx and the leftmost to the 2-Tx / 2-Rx scenarios. First of all, we can observe that the BPS throughput curves of OFDM and single-user MC-CDMA are close to each other, namely within 1 dB for most of the SNR range. This is surprising, considering that the fixed-mode MMSE-BDFE JD assisted MC-CDMA scheme was reported to exhibit around 10dB SNR gain at a BER of 10-3 and 30dB gain at a BER of 10-6 over OFDM [3, 67]. This is confirmed in Figure 7(b) by observing that the SNR difference between the and markers is around 10dB, regardless whether the 4, 2 or 1 BPS scenario is concerned.

Let us now compare the SNR gains of the adaptive modems over the fixed modems. The SNR difference between

the BPS curve of AOFDM and the fixed-mode OFDM represented by the symbol at the same throughput is around 15dB. The corresponding SNR difference between the adaptive and fixed-mode 4, 2 or 1 BPS MC-CDMA modem is around 5dB. More explicitly, since in the context of the WATM channel model [4, pp.476] fixed-mode MC-CDMA appears to exhibit a 10dB SNR gain over fixed-mode OFDM, the additional 5dB SNR gain of AMC-CDMA over its fixed-mode counterpart results in a total SNR gain of 15dB over fixed-mode OFDM. Hence ultimately the performance of AOFDM and AMC-CDMA becomes similar.

Let us now examine the effect of ST block coding. The SNR gain of the fixed-mode scheme due to the introduction of a 2-Tx / 1-Rx ST block code is represented as the SNR difference between the two right most markers. These gains are nearly 10dB for fixed-mode OFDM, while they are only 3dB for fixed-mode MC-CDMA modems. However, the corresponding gains are less than 1dB for both adaptive modems. Since the transmitter power is halved due to using two Tx antennas in the ST codec, a 3dB channel SNR penalty was already applied to the curves in Figure 7(b). The introduction of the second receive antenna instead of the second transmit antenna eliminates this 3dB penalty. Finally, the 2-Tx / 2-Rx system gives around 3-4dB SNR gain in the context of fixed-mode OFDM and a 2-3dB SNR gain for MC-CDMA, in both cases over the 1-Tx / 2-Rx system. By contrast, the gain of the 2-Tx / 2-Rx scheme over the 1-Tx / 2-Rx based adaptive modems was, again, less than 1dB in Figure 7(b). More importantly, for the 2-Tx / 2-Rx scenario the advantage of employing adaptive modulation vanishes, since the fixed-mode MC-CDMA modem performs as well as the AMCCDMA modem in this scenario. Moreover, the fixed-mode MCCDMA modem still outperforms the fixed-mode OFDM modem by about 2dB. We conclude that since the diversity-order increases with the introduction of ST block codes, the channel quality variation becomes sufficiently low for the performance advantage of adaptive modems to vanish. This is achieved at the price of a higher complexity due to employing two transmitters and two receivers.

Turbo-Coded Fixed Modem

When channel coding is employed in the fixed-mode multi-carrier systems, it is expected that OFDM benefits more substantially from the frequency domain diversity than MC-CDMA, which benefited more than OFDM without channel coding. The simulation results depicted in Figure 8 show that the various turbo-coded fixed-mode MC-CDMA systems consistently outperform OFDM. However, the SNR differences between the turbo-coded BER curves of OFDM and MC-CDMA are reduced considerably.

Turbo Coded Adaptive System

The performance of the concatenated ST block coded and turbo convolutional coded adaptive modems is depicted in Figure 9. We now applied a different set of switching levels, namely the optimum set of switching levels designed for the relatively high uncoded BER of 3 x 10^{-2}, rather than 10^{-3}, which was then further reduced by turbo coding. More explicitly, this uncoded target BER was obtained from the relationship of the uncoded and the turbo coded BPSK modems employing the same coding parameters over AWGN channels, with the ultimate objective of obtaining a coded BER of less than 10^{-7} for our adaptive modems. However, our simulation results yielded zero bit errors when transmitting 109 bits, except for some SNRs, when employing only a single antenna.

Figure 9(a) shows the BER of our turbo coded adaptive modems, when a single antenna is used. We observe in the fig-

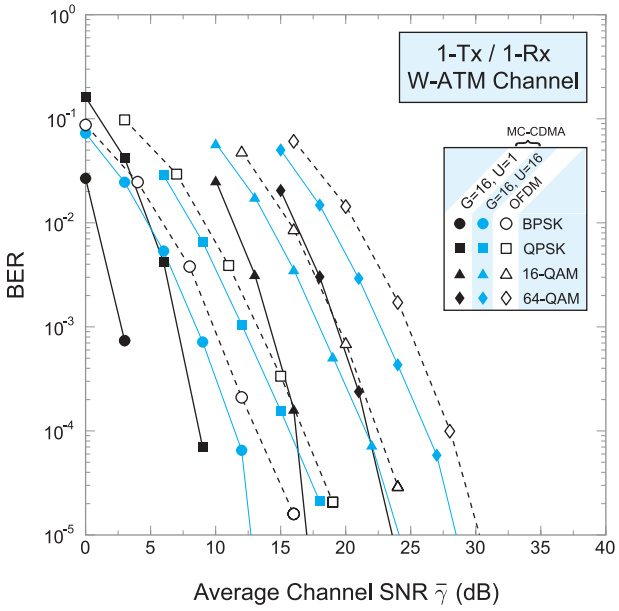


Figure 8 Performance of turbo convolutional coded fixed-mode OFDM and MC-CDMA over the WATM channel of [4, pp.476]. JD MC-CDMA still outperforms OFDM. However, the SNR gain of JD MC-CDMA over OFDM is reduced to 1-2dB at a BER of 10-4

ure that the BER reaches its highest value around the "avalanche" SNR point, where the adaptive modulation scheme consistently activates 64-QAM. The system is most vulnerable around this point. In order to interpret this phenomenon, let us briefly consider the associated interleaving aspects. For practical reasons we have used a fixed interleaver length of L = 3072 bits. When the instantaneous channel quality was high, the L = 3072 bits were spanning a shorter time duration during their passage over the fading channel, because they were delivered by a six times lower number 64-QAM symbols, than in case of BPSK symbols. Hence the channel errors appeared more bursty, than in the lower-throughput AQAM modes, which transmitted the L = 3072 bits over a longer duration, hence dispersing the error bursts over a longer duration of time. The associated more random dispersion of erroneous bits enhances the coding power of the turbo code. On the other hand, in the SNR region beyond the 'avalanche' SNR point the system exhibited a lower uncoded BER, reducing the coded BER even further. This observation suggests that further research ought to determine the set of switching thresholds specifically and directly for a coded adaptive system. Alternatively, adaptive threshold-learning techniques, such as that proposed by Tang [162] have to be designed.

We can also observe that the turbo coded BER of AOFDM is higher than that of AMC-CDMA in the SNR rage of 10-20dB, even though the uncoded BER is the same. This appears to be the effect of the limited exploitation of frequency domain diversity in coded OFDM, compared to MC-CDMA, which leads to a more bursty uncoded error distribution, hence degrading the turbo coded performance. The fact that ST block coding aided multiple antenna systems show virtually error free performance corroborates our argument.

Figure 9(b) compares the throughputs of the coded adaptive modems and the uncoded adaptive modems exhibiting a

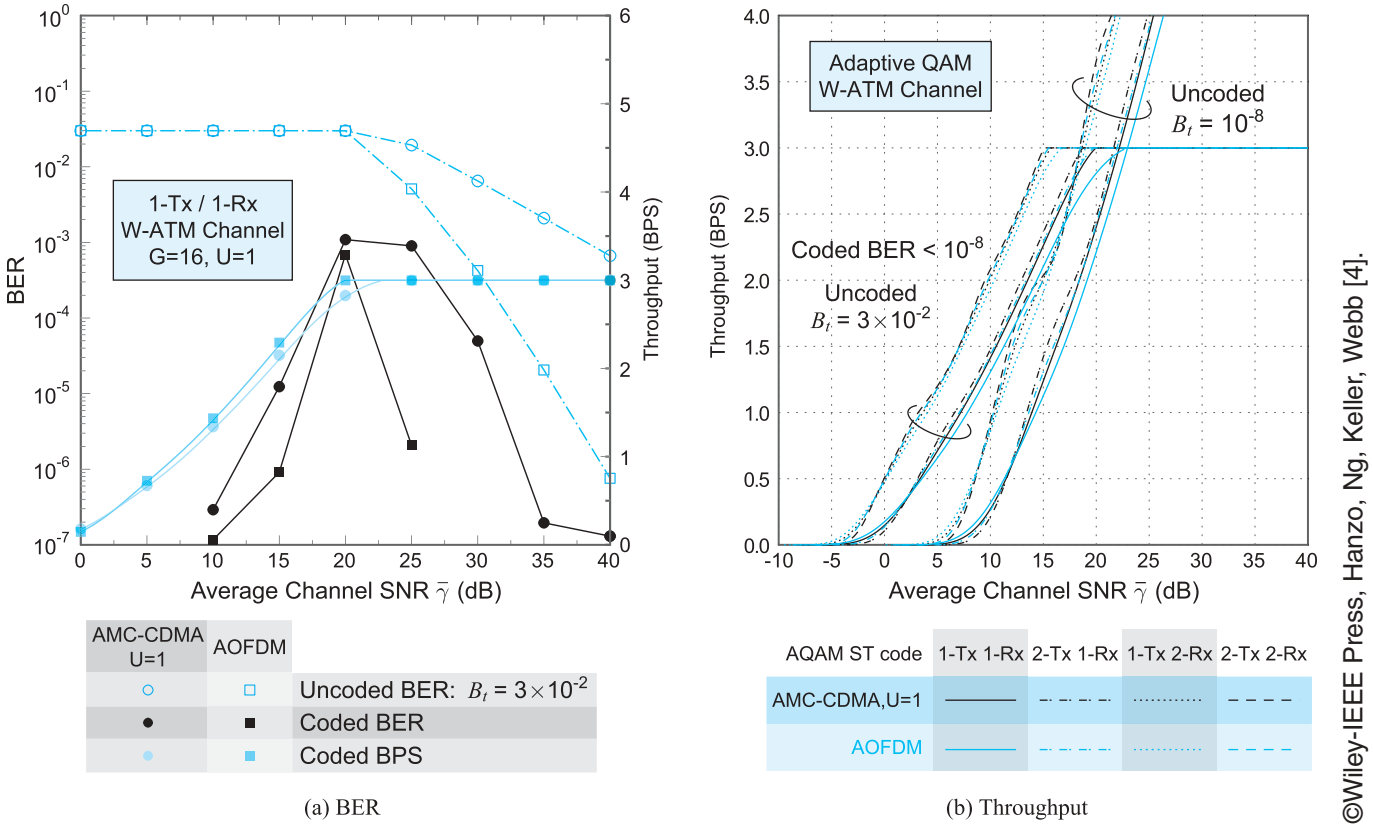


Figure 9 Performance of the concatenated ST block coded and turbo convolutional coded adaptive OFDM and MC-CDMA systems over WATM channel of [4, pp.476]. The uncoded target BER is 3x10^{-2}. The coded BER was less than 10^{-8} for most of the SNR range, resulting in virtually error free transmission. (a) The coded BER becomes higher near the 'avalanche' SNR point, when a single antenna was used. (b) The coded adaptive modems have SNR gains up to 7dB compared to their uncoded counterparts achieving a comparable average BER

comparable average BER. The SNR gains due to channel coding were in the range of 0dB to 8dB depending on the SNR region and the employed scenarios. Each of the two distinctive bundles of throughput curves corresponds to the scenarios of 1-Tx / 1-Rx OFDM, 1-Tx / 1-Rx MC-CDMA, 2-Tx / 1-Rx OFDM, 2-Tx / 1-Rx MC-CDMA, 1-Tx / 2-Rx OFDM, 1-Tx / 2-Rx MC-CDMA, 2-Tx / 2-Rx OFDM and 2-Tx / 2-Rx MC-CDMA starting from the far right curve for the throughput values higher than 0.5 BPS. The SNR difference between the throughput curves of the ST-plus turbo-coded AOFDM and those of the corresponding AMC-CDMA schemes was reduced compared to the uncoded performance curves of Figure 7(b). The SNR gain owing to ST block coding in the context of AOFDM and AMC-CDMA was limited to about 1dB due to the halved transmitter power. Therefore, again, ST block coding provides limited additional gains in the context of adaptive modems, since either of these fading counter-measures is capable of mitigating the effects of fading.

Conclusion

This companion paper has provided a system design example and characterised the achievable performance of OFDM/MC-CDMA multicarrier systems.

Explicitly, the performance of ST block coded constant-power adaptive multi-carrier modems employing optimum SNR-dependent modem mode switching levels were investigated. The adaptive modems maintained the constant target BER, whilst maximising the average throughput. As expected, it was found that ST block coding reduces the relative performance advantage of adaptive modulation, since it increases the diversity order and eventually reduces the channel quality variations. When turbo convolutional coding was concatenated to the ST block codes, near error-free transmission was achieved at the expense of the halving the average throughput. Compared to the uncoded system, the turbo-coded system was capable of achieving higher throughput in the low SNR region at the cost of higher complexity. The study of the relationship between the uncoded BER and the corresponding coded BER showed that adaptive modems obtain higher coding gains, than that of fixed modems. This was due to the fact that the adaptive modem avoids burst errors even in deep channel fades by reducing the number of bits per modulated symbol eventually to zero.

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VTS Board of Governors Meeting 17 May 2004

The VTS Board of Governors' meeting met at VTC2004-Spring in Milan, Italy, on 18 May 2004. Elected Board members Charlie Backof, Dennis Bodson, Tracy Fulghum James Irvine, Tad Matsumoto, George McClure, Sam McConoughey, Tom Rubinstein, Eric Schimmel, Gordon Stüber, Ray Trott and Jim Worsham were present, along with J.R. Cruz (Jr. Past President), Harvey Glickenstein (VP Land Transportation), Jae Hong, Lee. Chair VTC 2003 Spring, Glenda McClure (Conference Coordinator), Fotini-Niovi Pavlidou (Chair of the Greek Chapter), Tan F. Wong (Editor of the Transactions on Vehicular Technology) and Fu-Chun Zheng (Chair of VTC2006-Spring).

The minutes of the previous meeting of 7 February 2004 were approved.

Secretary's Report: Tracy Fulghum reported that the electronic distribution of meeting handouts the week before the meeting, rather than copying over a hundred pages and sending it to the meeting venue, seems to have been successful and will continue.

Treasurer's Report: George McClure reported that the society had approximately 4100 active members, with an additional 1317 members in arrears. The IEEE is replacing the Book Broker program with the Conference Publication Program to take account of the fact that conference proceedings are now electronic. This will pay $25 per paper for solely IEEE conferences, or $12.50 for financially co-sponsored conferences. Compared to the hard copy proceedings of VTC the Book Broker programme used to purchase, the net effect will be a reduction in conference revenue to the Society of about $25k. The page budget for Transactions on Vehicular Technology is 2000 pages for 2005. The non-member subscription has been increased, but the number of subscriptions has fallen in line with the IEEE average, which means that overall income has fallen here too.

President's Report: Charles Backof reported that the IEEE was currently conducting a survey of non-recurring society members (i.e., people who retained membership of IEEE, but dropped society membership. The results would be made available tot the society in due course. A request had been received to technically co-sponsor the International Symposium on Wireless System and Networks (ISWN) to be held in April 2005 in Bahrain. The first symposium (this would be the second) had 70 papers. This was agreed.

After a review of verified roll calls for Board of Governors meeting for the past three years, a Board member was identified as being in non-compliance with the requirements for meeting attendance as set out in the Society Bylaws. It was decided that he will not be removed from the board, but will be excluded from approval for the re-election slate.

Publications: Editor Tan F. Wong reported on Transactions on Vehicular Technology. There has been a net gain of five Associate Editors (6 have left their positions while 11 came in). The transactions will easily hit its budgeted 2000 pages, with very few accepted papers in backlog. An effort is being made to get Associate Editors to get manuscript cycle time down. A six month deadline for manuscript revision is being imposed to get lingerers out. The acceptance rate is 45% over one year, with the number of average pages per paper at 10. It was agreed to impose a mandatory overlength charge of $220 for papers over 8 pages, effective 1 July 2004.

A proposal was discussed for additional funds for administrative assistance in the editorial operations of Transactions on Vehicular Technology. The funds are essentially for a half-time administrative assistant from the University of Florida. After some discussion, the proposal was agreed, with a ceiling of $30 000 per year, to be administered quarterly as a foundation donation to the University of Florida, beginning (retroactively) 1 October 2003. There was additional discussion with regard to the subscription cost of Transactions. It was noted that paper copy plus electronic access was the only option for Transactions; there was no separate option for electronic access only. It was therefore

agreed to set the subscription rate for Transactions on Vehicular Technology at $22 per year for electronic subscriptions and $45 per year for electronic plus paper subscription.

James Irvine gave a report on the VTS News. A number of special issues are in the works, e.g. an issue on research in Europe. The VTS News is on track for becoming a magazine by 2006. The new two color processes are taking a lot of time for translating diagrams, etc., and was agreed to increase the budget by $7500 to allow graphic design support for the typesetting work.

Digital Archive: Two options were considered - an initial archive of all early pre-1988 papers not already available through Xplore, and with a second phase with all Society papers, or to do everything at once. It was agreed to go forward with the all at once scheme.

Society Constitution: Dennis Bodson presented the proposed revisions to the Society Bylaws. Most of the revisions are editorial. After some discussion, it was agreed not to change Section III-5.0 and IV-4.0, which would have had the effect of increasing the amount of time someone who had served as president would have to wait before being eligible again. The remaining changes were carried.

Membership Development: Roger Madden presented a Membership Development Plan. It was agreed to raise the Membership Development budget from $10 200 to $20 000 per year, with a case-by-case approval for each action by the committee. It was agreed to offer free membership for the remainder of this year to attendees of VTC Spring 2004. Tad Matsumoto was requested to come up with a Europe specific list of Distinguished Lecturers to reduce travel costs.

Nominations Committee: A slates of ten candidates for elections for the 2005-2007 term of the Board of Governors elections was agreed: Charlie Backof, Dennis Bodson, Tad Matsumoto, Sam McConoughey, J.R. Cruz, Eric Schimmel, Jae Hong Lee, Harvey Glickenstein, Vijay Bhargava, and Lajos Hanzo.

Standards: Dennis Bodson reported on Standards. As SCC32 has officially dissolved, the VTS has taken responsibility for that standard, and things seem to be running smoothly. There was also some discussion of increasing the VTS's presence in 3GPP and other standards groups.

Conferences & Meetings: Dennis Bodson reported on VTC2004-Spring. Things are going well, and there is projected to be a $30 000 surplus. The President thanked TPC Chair James Irvine for his efforts in this Conference to a round of applause by the Board and attendees of the meeting. Glenda McClure reported on VTC2004-Fall. Registration was ready to roll, and authors needed to be notified, but otherwise the conference preparations were going well. Regarding VTC2005-Spring Stockholm, a contract has been signed with Clarion Hotel. Jan Uddenfeldt was named General Chair, while Jens Zander was named Technical Program Chair. A contract has been signed with the local Hotel Intercontinental for VTC2005-Fall in Dallas. W.C.Y. Lee and Steven Gray have been identified as TPC's.

General Chair Fu Chun Zheng presented a report on VTC2006-Spring in Melbourne. The working title of the conference is "VTC2006 May", as it will be in the Southern Hemisphere. The hotel has been selected, the Grand Hyatt Melbourne. David Everett has been named as TPC, and the date of the conference is 7-10 May 2006. There was some discussion about the technical committee wanting full paper review for this conference, as opposed to a paper summary review, as has been the norm for VTC. Generally, in Australia, papers are valued less if they appear in a summary reviewed conference. The President suggested a meeting with George McClure, and the Board would act on this at the September meetings.

The first Asia Pacific Wireless Communications Symposium (APWCS), in January of 2004, was a success. There were 61 registrants and about 33 papers. It is proposed that the second APWCS be held in August of 2005 in Saporo City, Japan, to be chaired by Prof. Hatori, and the Board agreed to provide technical support.

The next meeting of the Board of Governors will be at VTC2004-Fall in Los Angeles on Tuesday, 28 September 2004.

42 Volts—The View from Today

Thomas A. Keim, Massachusetts Institute of Technology

A few years ago, the automobile industry agreed to adopt standards for a new voltage for the production and use of electrical power. The perception was near universal that 14 Volts was at the limits of its capability, and that 42 Volts would be adopted in a rush. The universal perception was wrong. Since then, much of the auto industry has encountered hard financial times. In a totally separate development, parts suppliers introduced innovations at 14 Volts, some of which a few years ago were thought to require 42 Volts. Today, there are 42-Volt cars and trucks for sale, but only at numbers far lower than necessary to begin to achieve economies of scale. But the factor that caused the industry to develop the 42-Volt standard, the growth of electricity use on motor vehicles, continues with no sign of letup. Further, the true technical obstacles to adoption of 42 Volts have been discovered and at least provisionally solved. The way forward to cost-effective solutions for advanced automobiles is clearer today than it was in the past.

Introduction

Throughout the history of the automobile, the average load on the electrical system has been increasing, model year upon model year. The principal drivers of this trend have been the increasing use of electric power to perform secondary vehicle functions, which in earlier automobiles were performed by alternate means, and the increasing level of equipment on the average automobile. Electric windshield wipers and electric radiator cooling fans are examples of the former class, and the near-universal use of electric rear window defoggers is an example of the latter class. There is no reason to expect that this trend will not continue into the future.

For the most part, this evolution has been gradual, and the industry has responded by installing more powerful electric generators and larger batteries to service the gradually increasing load. In the 1950's, there occurred a conversion from 6-Volt to 12-Volt electrical systems, which made it possible to accommodate the larger load more economically. At that time, the automotive electrical system was much simpler than today, and this transition took place quickly, and without much, if any, increase in expense.

For well over a decade, visionaries within the industry have been questioning whether continued use of today's 14-Volt system will be the most economical way to provide electric power in the future. Even before 1990, SAE had organised a committee on Dual/Higher Voltage Electrical Systems [1]. By 1994, a series of workshops had begun at MIT, to address the possible future of automotive electrical distribution [2]. The successor to the workshops is the MIT/Industry Consortium on Advanced Automotive Electrical/Electronic Components and Systems (the MIT Consortium) [3]. One early product was the proposal of 42 Volts as a standard for automotive generation and distribution [4].

Implicit in this search for a new distribution system was the search for a cost-effective solution. The principal reason that the industry chose to come together to propose a standard was the belief that, by agreeing to a standard, parts complying with the standard would be produced in large volume (compared to the results for a company-specific, or proprietary, standard), and that the large volume would encourage parts suppliers and produce low component costs.

The case was made that future electrical components, processing higher levels of power and using semiconductors to control the primary component power flow, could be produced more economically, if they were designed to operate at a higher voltage [5].

Some argued that at the new voltage, power could be generated and distributed at a lower cost. Certainly, savings were expected in the wire harness. And savings could be projected for the generator, too.

Less expensive power generation and distribution to less expensive loads could result in a lower cost power system. Of course, this outcome depends on the projected savings being realised in both the pre-existing components being converted in voltage and in the new components. It also requires that little or no new equipment (components or functions not present in the present system) be required for the new system.

Although some projected that the new voltage would be a cost saving, the mainstream vision was never that the electrical system for a current production model would be made less expensive by adopting the new voltage. Rather, the goal was to make it possible for a future automobile, with a higher installed electrical load, to be made at lower cost than if the new voltage were not available.

But whether the vision was a cost saving, or simply a cost-effective way forward, auto companies and parts companies from all over the world endorsed the new standard. Many established substantial internal development programs to produce parts for the anticipated new systems. A positive-feedback instability developed. As each successive company announced a 42-Volt development program, other companies would reconsider their plans, and frequently increase their commitment. Expectations grew very high. The vision for the industry was of a cost-effective technology upgrade. But for each individual company, 42 Volts became an opportunity for new profitable product lines, an imminent threat to existing products, or both.

But in late 2004, adoption of 42 Volts for most manufacturers is viewed as a contingent possibility, rather than as a firm plan. Most of the internally funded development programs have been stopped. The possibility exists that automotive electrical systems will continue their evolution without widespread adoption of 42 Volts. At the very least, the introduction of 42 Volts will be far slower than was anticipated only a few years ago.

This paper explores the reasons for this change of mind, and discusses the way forward from here.

Some of the potential obstacles to adoption of a new distribution voltage were apparent even as the proposal was being developed. Still others became evident as work progressed to develop the components of the planned new systems.

The Dual-Voltage Dilemma

One of the most important differences between changing distribution voltage now at the change of the millennium, compared to the 6-Volt to 12-Volt transition at mid-century, is the relative complexity of today's auto electrical system. The total number of electrical parts on a modern automobile, and the fraction of the total vehicle cost that they represent, bears no comparison to the first 12-Volt cars. Setting aside for the moment questions of technical feasibility, the act of developing a new part to functionally replace every electrical part on a modern automobile, even if the only difference in the new part is the input voltage, represents a monumental undertaking. It is far from clear that the non-recurring design and qualification expense could be economically recovered over the production life of a single vehicle platform.

To avoid this massive conversion expense, most parties considering a new distribution voltage have proposed dual-voltage systems. In these systems, the new loads that require or benefit from the new voltage, are provided power at that voltage, while a second 12-/14-Volt system provides power to legacy loads.

The adoption of a dual-voltage system quickly leads to a number of other system choices. Clearly, if there are loads at two voltages, there must be a power source at each voltage. Prime choices are a dual-output alternator and a DC/DC converter operating between the two voltage buses. Because the cost of each power source depends on its peak power, one is quickly lead to conclude that a dual-voltage system should use a battery at each voltage, to allow the power source to be sized only for the average power at that voltage.

Vehicle designers look at the resulting system, with two batteries and dual power sources, and conclude that this represents an unsatisfactory solution, certainly for the long run. Some manufacturers have at times suggested that they would not build dual-voltage systems. But in most cases, the dual-voltage solution has been accepted at least as a short-term solution, while most makers planning or producing 42-Volt dual-voltage autos envision going to a single-voltage solution at some point in the future.

With more detailed analysis, this seemingly understandable goal is not as clearly desirable as it may seem. Some loads

(incandescent filament lamps prime among them) do not scale well to higher voltages. A designer charged with eliminating all lower voltage loads must either do without incandescent lamps, or, alternatively, arrange to operate lamps in series strings, probably with some burnout protection circuit. It has been demonstrated that lamps can be successfully operated from 42 Volts using a relatively simple PWM control circuit. The cost, weight, and inefficiency of the potentially numerous PWM lamp controls must be weighed against the cost and weight of a potentially small battery and a voltage source, which itself probably comprises some form of a PWM circuit, most probably more complicated than the simple lamp driver.

The need to use dual voltage is thus seen as a necessary cost penalty for 42 Volts, at least in the short term, and probably for a very long time.

Technical Challenges for 42 Volts

In the years since the possible need for a higher distribution voltage has been established, investigators have identified a number of ways in which 42-Volt or dual-voltage systems are qualitatively different from 14- Volt systems. Each of these differences requires consideration at the system engineering level, and most require some additional features in the new bus architecture, which add to cost but not to end-user function. So cost-effective solutions to these technical challenges are required for 42-Volt or dual-voltage systems to succeed.

Electric Arcs

By far the most pervasive difference between 14 Volts and 42 Volts is the behaviour of electric arcs. At 14 Volts, with all common materials of construction for automobiles, arcs are inherently unstable. If a circuit is interrupted, for example by a relay or switch, an arc will occur, but it will persist only as long as an inductive (L di/dt) voltage exists to sustain it. When the voltage across the arc falls to or below 14 volts, it self-extinguishes.

At any voltage much above 14 Volts, certainly at 42 Volts, an arc between two electrodes separated by a small gap is stable; it can theoretically burn indefinitely. There is an exception to this statement; for very small currents, arcs exhibit unstable, self-extinguishing behaviour at 42 Volts. In practice, arcs do not burn indefinitely. Most often, the process that caused the electrodes to be separated does not stop, causing the electrode gap to increase with time. At a long enough gap, the arc becomes unstable and self-extinguishes. In extreme cases, the melting of the electrode is the process that lengthens the gap until extinction occurs.

This difference in behaviour can, in unfavourable cases, result in dissipation in electric arcs which is much greater at 42 Volts than is possible at 14 Volts.

Although this problem had been recognised by several companies, it was not widely discussed in public until it was brought to the attention of the MIT Consortium by Yazaki in 1999. The subsequent public investigation quickly defined and bounded the problem.

The Videos—The issues of electric arcs at 42 Volts has been dramatised by the existence and frequent showing of a number of very dramatic videos. Some of these videos make arc welding look tame by comparison, and truly remarkable component damage is sometimes shown. These videos have been responsibly prepared and presented within the automotive electrical systems community, but their adverse impact on the larger automotive community may have improperly damaged the image of 42 Volts. Almost without exception, these videos present the consequences of failing to consider arcs in the design of 42-Volt systems. They are examples of bad design, and in extreme cases negligently bad design. There are far fewer videos and before-and-after photos of the consequences of good and responsible design.

The fact is that the possibility of arcs must be considered in the design of 42-Volt systems, and the possibility of arcs limits the applicability of 14-Volt parts at the new voltage. But the possibility of arcs does not make it impossible to design safe and cost-effective 42-Volt systems.

Fuses—One of the earliest findings in the investigation of 42 Volts was that existing automotive fuses could not be used. At 42 Volts, 14-Volt fuses fail dramatically, with an arc persisting for some time within the fuse body before eventually extinguishing, and frequently with the fuse body bursting into flame. Much to their credit, the automotive fuse industry, despite being very small and lightly capitalised by industry standards, rolled up their sleeves and developed new designs that did work satisfactorily [6]. These new fuses are compatible with present production practice, and samples quickly became widely available. The apparent ease with which the industry dealt with the 42-Volt fuse problem may have set expectations which suppliers of other parts could not so quickly meet.

Switches and Relays—The problem of 42-Volt arcs is not so severe in switches and relays. The designers of these components have control over how fast their contacts separate, and they have the option of putting more than one set of contacts in series. So it is fairly straightforward to design a switch or relay for 42 Volts. Of course, switches and relays designed for 14 Volts are unlikely to be satisfactory at the new voltage, unless they are switching loads below the threshold current for unstable arcs.

Connectors—Connectors are another matter. Most connectors are not intended to be mated and unmated under load. But at 14 Volts, the practice has no practical adverse consequences, so it has become widespread in the repair industry. But at 42 Volts, the consequences can be significant. Even a single disconnection under load can render a connector unsuitable for further service. With few exceptions, the connector designer cannot control the rate at which the contacts separate; that is generally determined by the service technician. So the principal design remedy available for switches and relays does not apply to connectors.

The industry has not selected a standardised response to the need for 42-Volt connectors. In part, this is due to there being no single clearly superior choice, but in part it is also due to a diverse range of reasonable choices. A strong case can be made for abandonment of the practice of mating or unmating connectors under load. The provision of a single, accessible master switch could make this change easily acceptable.

Alternatively, selective application of special connectors could be used. Many loads at 42 volts can be connected or disconnected under power with no more consequence than at 14 Volts, because their currents fall below the threshold. Only a few loads may need special treatment, and for these, the industry has demonstrated a range of practical choices. A sense pin can break before the power pins on disconnection, and the sense pin break can drive a relay that disconnects the circuit. Some connectors introduce a resistance in series with the load before the final contact parts. And in one case, a very promising contact alloy selection reportedly offers damage free mating and unmating under a range of conditions covering many practical loads [7]. Few if any of these technologies are in parts catalogues today, but the way forward to cost-effective, arc-insensitive connectors seems to be open.

Parallel Arcs—In addition to switches, relays, and connectors, the difference in arc behaviour at the two voltages requires consideration of the consequences of arcs at locations where no arcs are anticipated. The first class of such arcs

occurs as a result of faults to ground. Such a fault can occur when an energised wire breaks and falls against the auto body, or when a portion of the body or frame cuts through wire insulation. These arcs are called parallel arcs, because they exist in parallel to the load.

Parallel arcs tend to be high current events. The source voltage is divided between the arc voltage, and voltage across the impedance in series with the arc (including the source impedance). Most commonly at 42 Volts, a substantial portion of the source voltage appears across the series impedance. For this to happen, the circuit current must be many times the design current, and the most common consequence is that a fuse blows, extinguishing the arc.

It is not uncommon for arc currents to be intermittent, even with nominally dc power supplies, and in the event of an intermittent arc, it is formally possible to dissipate much power in the arc for a long period of time, without blowing the fuse. We investigated this eventuality at MIT, and our observation was that this subclass, parallel arcs that do not blow fuses, was a relatively small threat. The duty ratio of the intermittent current must be very low to prevent fuse blowing, so low that this event will represent only a very small fraction of cases. And, with acceptable duty ratios and reasonable series impedances (values representative of an automotive wire harness), the resulting arc is not very energetic. In our experiments, we commonly saw melting of wire insulation and whiffs of smoke, but only in the immediate vicinity of the arc. We did not see open flame [8].

Series Arcs—The other class of unintentional arcs is series arcs. Here the arc occurs in a path that is in series with the load. Connector arcs are series arcs. Because the load is in series, the arc current cannot exceed the load current, and fuses will not act. The most common place for a series arc is at a connector, if not a connector being deliberately opened, then one that has been improperly mated.

A series arc can be viewed as a member of a class of failures, all of which comprise an unintended high impedance in series with the load. Corroded connectors and partially but not totally severed wires are other members of this class. Any of these failures can cause a local dissipation of energy intense enough to overheat and even to ignite the failure site. These failure modes exist in today's automobile fleet, and there is no protection against such failures in today's automobiles. It is far from apparent that the possibility of a stable series arc changes very much the overall risk to a vehicle from this class of faults, taken as a whole.

Finally, it is possible to develop active circuitry that detects an electric arc and disconnects the failed branch. Arc detection is sufficiently cost-effective that it is used in the ac service in new residences in many countries [9]. It is also now being marketed for electric power systems in transport category aircraft. These both represent AC applications, but some of the same suppliers indicate that DC arc detection can be performed, as well [10].

Electric Arc Summary—Arc behaviour is demonstrably different at 42 Volts than at 14 Volts. This difference can be used to make very dramatic videos. But the videos show cases which cannot exist or should not be permitted to exist in a practical automobile. When a detailed circuit-by-circuit, failure-by-failure analysis is made, it is probable that the risk of damage by arc is negligible or acceptable in the vast majority of cases. For a few circuits and/or failure modes, new technology may be required. For these cases, a range of cost-effective solutions exists. In short, arcs are a new technical challenge for the designer, but they do not pose an insurmountable obstacle to using 42 Volts in automobiles.

Bus-To-Bus Faults

The dual-voltage automobile has a new failure mode, that of a short between the high-voltage and the low-voltage buses. This problem of course cannot exist without two voltages, but in a dual-voltage automobile, it can be imagined to be relatively common, as designers expect to feed some loads with both voltages, and to mix voltages within bundles of the wire harness.

A "hard" (low-resistance) short between the two supply voltages will almost certainly blow a fuse. But what happens after that depends on many factors. One cannot control in general which of the two affected fuses will blow first and it can be established that there are many operating cases in which the second fuse does not blow.

In general, the requirement for a safe outcome should be that both affected fuses clear. Some have argued that a final outcome with 14 Volts applied through the short to a 42-Volt load is safe. This is defensible regarding the stress on the 42-Volt component, but there is a hazard in that the short, while being low enough in resistance to allow for fuse clearing, is still a high enough resistance to produce hazardous local heating.

A working group was formed in Europe by the Sci-worx forum (which met originally under the German name Forum Bordnetz, then later used the name Forum Vehicle Electric System Architecture, and is now considering another name change), to make recommendations concerning design for safety in light of the possibility of a bus-to-bus short. Their recommendation comprised a zonal protection concept, in which conductors at different potentials were kept separate [11].

More recently, work supported by the MIT Consortium showed a simple, elegant design methodology that can guarantee clearing of both affected fuses by including simple active elements in the fusebox. The cost to implement this methodology is modest [12].

A similar, less severe, problem occurs when a load is fed from both voltages, using a common ground contact for both circuits. Should the ground contact be lost, the load is placed in an unusual state. In general, this state need not be hazardous to the load or the vehicle, but it is yet another failure mode to be considered during design.

In summary, the bus-to-bus short in dual voltage systems presents a new failure mode. Design methods, either involving vehicle layout or the inclusion of active elements in the fusebox, have been proposed and evaluated. This obstacle has been adequately identified and studied, and suitable countermeasures have been defined.

Corrosion

In 2002, an SAE Toptec included an important session in which the performance of electrical parts, under electrical stress were evaluated as a function of voltage in accelerated life tests in corrosive environments [13]. This session presented the independent, uncoordinated studies by a number of important contributors, but the independent works formed a surprisingly coherent theme. Although the physics of the processes being tested include many processes, including electromigration and surface insulation degradation, the studies were generally referred to as corrosion studies, and that name, although at least partially misleading, is the one used here.

In general, the deterioration of the parts was troubling. And parts tested at 42 Volts deteriorated substantially faster than parts tested at 14 Volts. But other than a general caution that one should be careful when using parts designed for 14 Volts at 42 Volts, it is hard to draw any conclusion from this session, or from any other source which has come to the author's attention.

Because the investigations were in almost every case accelerated tests, it is difficult to form any firm conclusion about the suitability of any given part for a proposed service, other than service at 14 Volts in an automotive environment. The strength of the accelerating functions is not known, nor is the threshold between acceptable and unacceptable deterioration.

Compared to arcing or bus-to-bus faults, the state of knowledge and readiness of the automotive industry regarding the collective phenomena referred to as corrosion at 42 Volts is not far advanced. In part, this is the case because the system engineers who lead the early efforts understand the threats of arcing and faults, and are comfortable dealing with these problems. The perception has been that corrosion is "just a materials problem" and that suitable solutions can readily be found.

It is the author's perception that the problem of "corrosion" will not stand in the way of use of 42 Volts in automobiles. Certainly trackless trolleys and streetcars work in exactly the same environment as automobiles, using voltages far above 42 Volts, and with product lifetimes and duty cycles far in excess of the automotive standard. But the present state of uncertainty will prompt early adopters to design more conservatively than the mature economic optimum, willingly incurring a probable penalty in system cost for a reduced risk of a systemic reliability problem. As experience is accumulated with parts working in the field at 42 Volts, unneeded conservatism will gradually be eliminated, and parts reflecting the true economic optimum will emerge.

Present Status

The previous paragraphs summarise the remarkable work that the automotive electrical community has done in finding, evaluating, and fixing the obstacles to application of 42 Volts. A number of important, and sometimes fascinating, technical problems have been uncovered. In each case, one or more solution(s) have been found. Despite considerable searching, the industry has not found a showstopper problem that would derail the use of 42 Volts.

Yet the industry is at a standstill regarding this technology. The reason is not technological: it is economic.

There are two economic challenges. The first is the financing of transition costs. This is not a new problem; it occurs with every technological transformation, and the auto industry solves it all the time. The second economic challenge is to identify the value that justifies the expense.

It is apparent that there is a cost required to implement 42 Volts. The source of cost is evident in a dual-voltage car, and even in a pure 42-Volt application, parts which perform functions that are presently being adequately performed at 14 Volts are likely to cost more, at least until volume builds to comprise a substantial fraction of the world's production.

So the early vision of 42 Volts as a cost reduction has proven to be unrealistic. But there is still the vision of 42 Volts as a cost-effective way to get more electric functions on the vehicle than is possible today.

To be selected on this basis, 42 Volts must be the only way, or the least expensive way, to get the required level of power and function, and the cost must still be low enough so that the vehicle designer does not reconsider the specifications for power and function.

The electric equipment market has changed to make it harder for 42 Volts to meet this selection criterion. Important electric functions including electric power steering and idle-stop operation, have been introduced to the market as 14-Volt functions. (There remains some question whether the 14-Volt implementations can be applied to the full range of light car and truck sizes, but prototype idle-stop systems have been demonstrated at 14 Volts even on large American V8 engines.) The output capability of automotive alternators has been increasing. Electromagnetic engine valve actuation (an important electrical load) has faded into the background, as more advanced mechanical valve actuation systems are implemented.

As it becomes possible to do more and more with 14 Volts, the auto companies have strong incentives to put off adoption of 42 Volts. Even if a given function can eventually be implemented less expensively at 42 Volts, the incentives are all negative for the early adopter. Each of the technical obstacles discussed above must be dealt with be any 42-Volt design. With limited experience with this new technology, a design error is more possible for the first/early adopter. Risk of high warranty expense and/or reputation for low reliability and poor quality is high. Then too, the suppliers will look to recover much of their investment in the technology in business dealings with early adopters.

At present, there are few vehicles that need 42 Volts, and there are powerful incentives not to rush to the new technology.

Just as each company to start a 42-Volt development program or to plan a 42-Volt product launch generated a flurry of interest and then activity among other companies, so has it been the case that each company to abandon its plans causes reconsideration at those companies which still have programs. Either out of embarrassment, or in a desire to demonstrate that they have learned from their previous excessive enthusiasm, decision-makers may choose for their company to have absolutely no association with 42 Volts.

In late 2002, one manufacturer put the incremental cost of a 42-Volt system, including only an integrated starter-generator, at between 555 and 1130 Euros [14]. The author concludes that these costs are difficult to justify on the basis of increased fuel economy.

Even in the face of such a negative outlook, there are two 42-Volt vehicles in production, and a few more still being developed [15,16]. Evidently the long-term prospect remains attractive, even if the short term is not.

Future Prospects

Just as expectations were once unreasonably high, they are now unreasonably low. The fundamental reasons for considering a voltage change are as sound as they ever were. There is no let-up in the growth of electricity use in automobiles. If anything, with increasing adoption of electric power steering and idle-stop operation, the rate of growth is increasing.

The work that has been done in the past several years has identified important differences between 42 Volts and 14 Volts, which require that 42-Volt systems and their components be designed with an awareness of these differences. The good news is that we know that 14-Volt systems cannot be converted directly into 42- Volt systems. However, for each technical difference, we have good ideas how to proceed to design the 42-Volt system.

Based on the work we have seen to date, 42 Volts will require a cost premium, but with sound design, it is easy to imagine that that premium will be 50 or 100 Euros, not ten times that much. None of the technical challenges discussed above require an expensive new direction.

50 Euros is still too much cost, just to have 42 Volts, but so is even one Euro. But at 50 Euros, it is plausible to believe that some new capability may be enabled, for example, electric turbo boost, which produces an overall vehicle benefit that exceeds the cost. It is also plausible that the voltage change will permit cost reductions in other systems which

may be specified on future cars, which can be implemented at 14 Volts but are more economical at a higher level.

As both the unrealistic optimism of the past, and the pessimism of the present give way to realism in the future, we will continue to see more electricity use on automobiles. At some point, we may see some of that use migrate tot 42 Volts.

Conclusion

The idea of 42 Volts in auto electric systems has had in interesting and dynamic history. The whole idea is driven by the ongoing growth in electricity use on motor vehicles, a trend that continues and may be accelerating. About the year 2000, a huge bubble of enthusiasm for 42 Volts resulted in activity all over the world. Investigators identified the important technical questions about application of 42 Volts in automobiles, and made major progress toward finding answers. But as automakers planned to implement 42 Volts, two things happened. First, with a few exceptions, they reconsidered their efforts and cancelled their programs. And second, the electric equipment market evolved so that applications that were once thought to require 42 Volts can now be implemented at 14 Volts. (The second event may have contributed to the first.)

The bubble of enthusiasm came to be replaced with a widespread disillusionment. It is ironic, but when no one knew what it took to implement 42 Volts, everyone was high on the prospect. But now that we know what it takes, and it is not that bad, opinions are nearly uniformly negative.

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Land Transportation

Harvey Glickenstein, Senior Editor

Seattle City Council approved funding for the South Lake Union Streetcar project. The 2.6-mile line would be funded by a tax on property owners along the route that is expected to raise about $25 million supplemented by state and federal money. No city general fund money will be used on the project. Proponents of the line point to the successful streetcar system in Portland, Oregon that is owned by the city but operated by Tri-Met, the operator of the light rail lines in Portland.

Since the city is precluded under state law from operating a transit system, they may contract with Sound Transit, who is currently building a light rail line as well as operating commuter service in Seattle and a light rail line in Tacoma, to operate the Seattle streetcar line.

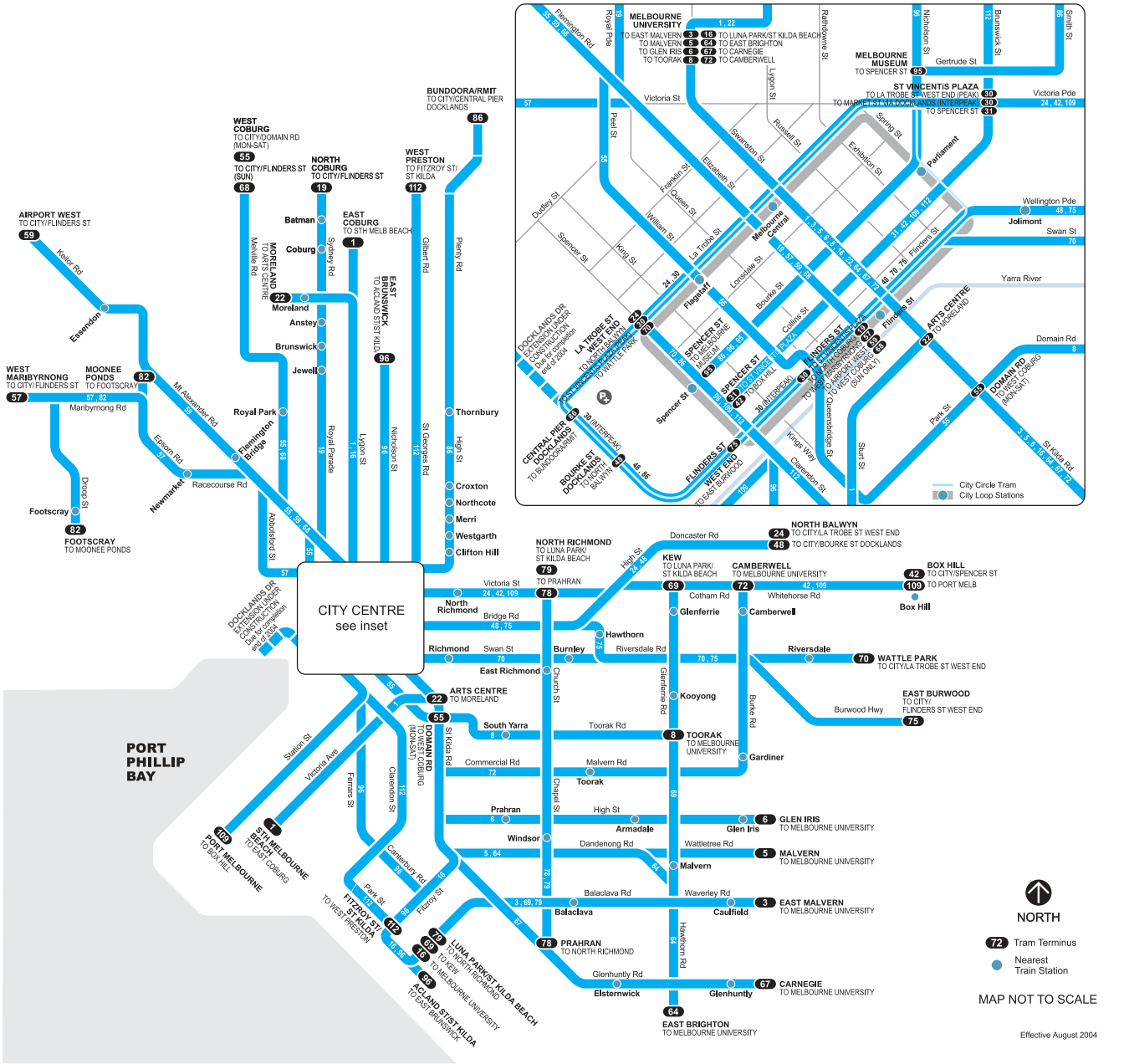
Yarra Trams is extending the Melbourne tram network to the Docklands area. The $A7.5 million extension will be from La Trobe Street along Harbour Esplanade and Docklands Drive to Central city Studios. Both the Route 48 and Route 30 trams will serve the new route. The 0.6-mile long extension is expected to be completed by the end of this year.

This is the first modernization to take place since Yarra Trams took over responsibility for the entire Melbourne tram network on April 18, 2004.

In 1999 the Victoria State Government entered into contracts with Yarra Trams and with National Express Group Australia (NEGA) to share operation of the tram network. One company received the contract for the lines which were basically north-south and the other received the contract for the lines which were basically east-west, although there were portions where trams of both operators used the same tracks.

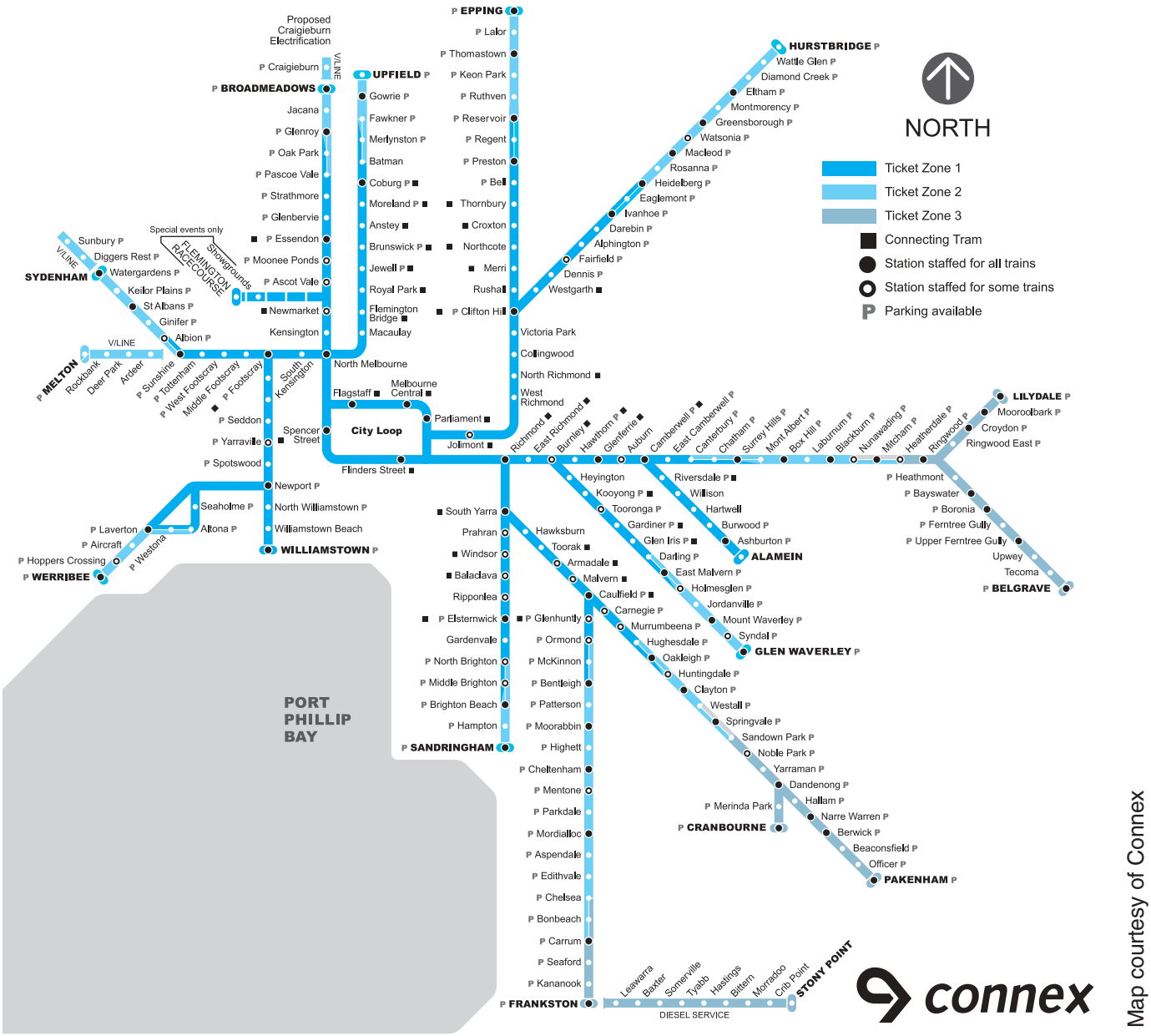
At the same time, the Victoria Government entered into contracts with Connex and NEGA to share the operation of the electrified commuter rail system. While an attempt was made to segregate the commuter rail operation as much as possible, some sharing of track was required in this operation as well.

Each operator maintained its own rolling stock and maintenance of way, although the rolling stock was purchased by the Victoria government. The fare system is a proof-of-purchase system using on-board validators on trams and buses and station validators on the railroad network. A unified fare instrument is used for all these operations. Maintenance of



Melbourne Tram Network.

Map courtesy of Yarra Trams



Map courtesy of Connex

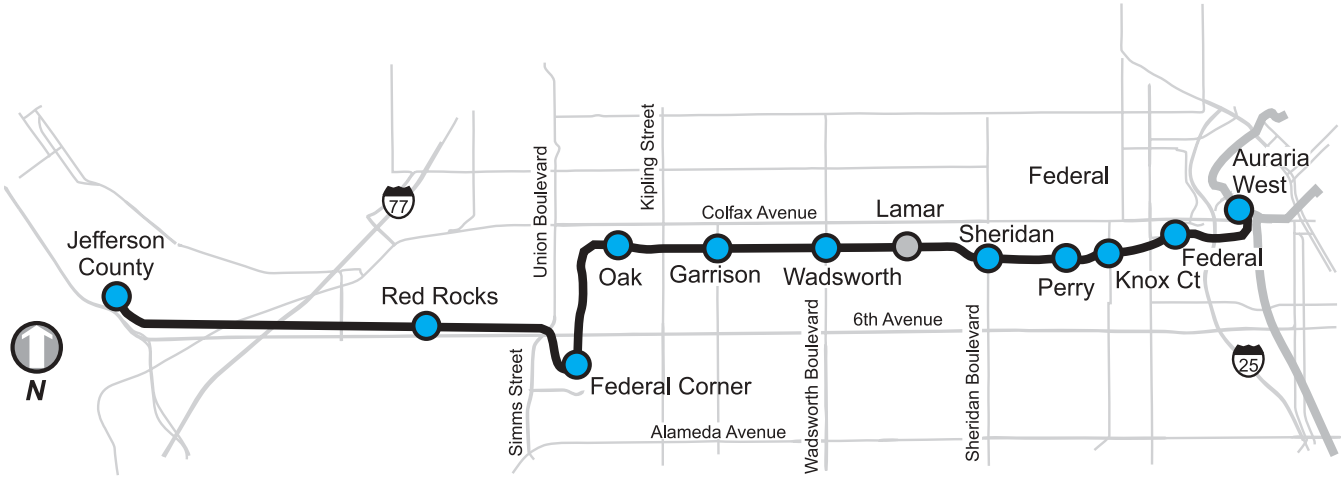
Melbourne Commuter Rail Network.

the fare system for all the operations was contracted out to another party.

In July, the Minister of Transport for the State of Victoria announced an initiative to convert the current ticketing system to a Smartcard system. The basic fare structure would remain the same. It would still be possible to buy disposable Smartcards on board trams and buses, as is possible with the existing ticketing system. It would also be possible to re-load value into prepurchased Smartcards. The call for tenders proposes that the new system will go into service in 2007 when the existing fare system contract expires.

The savings expected to result from the privatization of the two rail networks did not materialize. In 2002 NEGA walked away from its two contracts and the Victoria Government was required to hire a receiver to keep the trains and trams running. After extensive negotiations with Yarra Trams and with Connex, the Victoria Government announced in February that it had reached agreement for Yarra Trams to take over the entire tram network and for Connex to take over the entire commuter rail network under new 5-year agreements that would

Las Vegas monorail



Denver West Corridor Light Rail Extension

increase the original $A1.3 billion earmarked for these two systems for the next five years to $A2.3 billion.

The Las Vegas monorail went into revenue service on July 17. The new system connects nine casinos with the Las Vegas Convention Center and replaces a previous system that only served one casino.

The system was built by Bombardier, who has a five-year contract with two 5-year options to operate and maintain the system.

It is expected to be fully self-supporting financially. Fares and advertising revenues are projected to cover operating and maintenance costs as well as repayment of the tax-exempt non-recourse revenue bonds that were floated to finance the $650 million project.

The line is fully automated. It initially operated from 8:00 AM to midnight. In August the system the hours were extended to 6:00 AM to 2:00 AM in August.

At press time the monorail was closed due to two separate incidents of parts falling off the overhead vehicles. A reopening date had not yet been announced.

Madrid ordered 70 Citadis Trams from Alstom for use on two extensions totaling 20 miles. The trams will be delivered starting in 2006 for use on the extensions that are scheduled to go into revenue service in 2007.

Denver received a Record of Decision from the Federal Transit Administration that the proposed West Corridor Light Rail extension meets all of the requirements of the National Environmental Policy Act of 1969. The project is a proposed extension of the existing light rail line from Auraria West Station for 12.1 miles west to Golden Colorado.

Automotive Electronics

Bill Fleming, Senior Editor

DaimlerChrysler to Drop 42V System Development

After years of hype, it appears that development of 42-volt electrical systems may have hit a roadblock in the auto industry. At least that's the proclamation from DaimlerChrysler [1]. Stephan Wolfsried, vice president-electrical/electronics chassis, for Mercedes Car Group declares the "42-volt system is done with." The demise comes as a result of cost and the lack of 42-volt components.

"Complexity involved during the transition phase from 14-volt to 42-volt would have been uncontrollable. Neither are there 42-volt light bulbs, nor is it practical to transform the power supply for every LED and every microprocessor from a new 42-V standard, down to their present design value of 14-volt," Wolfsried said.

Other Daimler Chrysler Technology Decisions

Wolfsried [1] laid down another ultimatum: "Mercedes-Benz will not copy BMW's much-maligned iDrive instrument control system. Functions that nobody uses, and which benefit nobody have no place in the car," he said. He noted that in

the last year alone Mercedes had removed over 600 functions from its vehicles. Removed functions included, for example, the tunnel air-circulation system, which was activated by pressing the air re-circulation button for two seconds. The system immediately would close the air re-circulation flap and open the windows and sunroof a few inches to remove any contaminated or stale air that entered the car after the car passed through a tunnel.

"CD-ROM and DVD-based navigation systems also will be phased out in the next two years, because the discs tend to warp at temperatures above 113° F (45° C)," said Wolfsried [1]. DaimlerChrysler will switch to hard discs, along with Smart Media and Personal Computer Memory Cards as storage devices for future navigation systems. The goal here is twofold: (a) to improve the overall ownership experience, while (b) reducing quality glitches. Mercedes has been penalized of late in focus group studies because of less-than-stellar electronics system reliability. Customers complain that multiple buttons are confusing and systems break repeatedly. Mercedes wants to put a stop to this and boost quality in the process.

Mercedes also is shifting from fiber-optic cable to conventional copper for many vehicle communications applications because of problems related to the fragility of the fiber-optic cables.

MY 2005 Cadillac STS to have Intellibeam & LED Tail Lamps

The MY 2005 Cadillac STS is equipped with an "intellibeam" system [2]. This system automatically switches headlamps from high- to low-beam and back again when oncoming headlamps or forward lighting elements are sensed. The system uses a CMOS light sensor mounted on the back of the rearview mirror. The CMOS device includes a miniature camera, light sensors and microprocessor that sense oncoming light and perform object recognition. When the sensor detects an approaching vehicle's headlights or preceding vehicle's tail lamps, the system turns off the high beams gradually before it distracts other drivers. The system also detects and effectively ignores ambient light coming from streetlights, sign reflections, buildings and other sources. In situations where light from an approaching vehicle is more immediate, such as when cresting a hill, the system in that case reacts instantaneously, automatically and rapidly switching to low-beam.

Another lighting-related new technology involves the Cadillac STS use of LED tail lamps which are designed with indirect optics, an industry-first application. Each tail lamp incorporate 30 sources of illumination [2]. The use of indirect optics eliminates "pinpoints" of light normally associated with LEDs and enables an upscale, refined appearance when illuminated. On the STS, each tail lamp has two vertical arrays consisting of 15 LEDs, and each LED has 20 optical facets. This configuration enables precise illumination and the design flexibility needed to meet domestic or export requirements. The center high-mounted stop light on the STS also uses LEDs, and is only 12-mm thick, and consists of 78 points of illumination. A novel lens design incorporates the use of pillow optics, which replaces the "pinpoint" appearance, normally associated with LEDs, with a smooth, refined output of light.

High Beam Hopes for LEDs

A new breed of brighter LEDs is being designed into vehicles. Two LED suppliers — Lumileds Lighting, San Jose, CA; and Osram Opto Semiconductors, San Jose, CA — are working on 100-lumen designs that would replace incandescent bulbs in light assemblies on a one-for-one basis (as opposed to the diode clusters now required to replace a single incandescent bulb) [3]. Visteon (Dearborn, MI), a tier-one supplier, is currently talking to several automakers about employing LED-based headlights as soon as the 2008 model year. For suppliers of automotive LEDs, the Holy Grail remains the headlight. Most suppliers expect to see the first all-LED-illuminated vehicles reach the market within five years [3].

"This is a monumental change for the auto industry," said Jeff Erion, R&D manager for exterior systems at Visteon (which recently demonstrated a working LED-based headlight assembly [3]). "Since 1914, there has been only one way to create light on a car. Now we're looking at a technology that can replace every filament bulb on the exterior of every vehicle."

Electronically Actuated Windshield Wipers

The rear-window wiper is used on many types of vehicles (minivans, vans, SUVs, etc.). A typical rear-wiper assembly consists of a unidirectional electric motor with a shaft-mounted worm gear, a mating helical gear, and a mechanical crank mechanism. The crank mechanism creates reciprocating motion at the balance link, which translates into a bidirectional, limited-angle rotation of the output shaft. The traditional design has disadvantages of: mechanical complexity, multiple wear points, and inflexible performance (wipe angles and park positions are fixed by the linkage design).

Johnson Electric has developed a rear wiper without using a mechanical mechanism [4]. An electronic control unit directs four power MOSFETs that control power to the gear motor. Ramping-up the voltage to the motor at the start of a wipe cycle, and down at the end of the cycle, provides soft start/stop operation.

Bidirectional wiping action is achieved without linkages by electrically reversing the direct-drive gear motor. The wiper relies on a microprocessor to regulate system motion by precisely controlling the motor's speed, direction, and stroke. The motor uses a 16-pole magnet attached to the motor shaft, and two Hall sensors that send rotor position signals to a microprocessor. Cost advantages are obtained because one motor can now be used for many vehicle platforms, and also provide vehicle-specific performance. The electronically actuated wiper motor assembly gives a 40% reduction in mass, and a 20% reduction in size over traditional mechanical wiper assemblies [4].

140 Satellite TV Channels Transmitted to Vehicles

First, there were navigation systems using satellite guidance for cars. Then there was satellite radio. Now there is satellite TV with 140 channels available in your SUV, minivan or large sedan [5, 6]. Generally, to minimize distraction, in-vehicle TV monitors are mounted so drivers can't see them. KVH Industries, a maker of mobile electronics, began selling a satellite TV system called TracVision for installation in SUVs and minivans in September. The system includes a large, roof-mounted, pancake-shaped antenna, 31 inches in diameter and 5 inches high. KVH's suggested selling price is $2,295. However, if you can wait — Delphi, XM Satellite, Sirius, and Boeing are all working on more affordable, smaller-antenna, versions of satellite TV [5].

Toyota Prius is Overrated …
…No, It Actually Does It All

According to an Automotive News writer [7], "engineers have done a masterful job with the gasoline-electric Honda Civic Hybrid and the Toyota Prius. Those cars are technical marvels, probably the most advanced and complex production cars ever made. But, although the Prius we test drove had an EPA rating of 60 mpg city/51 highway, one of our staff members drove the Prius 331 miles in combined city-highway driving and got just 40 mpg, while others recorded 44 mpg to 48 mpg in city driving and about 40 mpg on the highway." The writer says, "I'd rather get an honest 50 mpg with a diesel car and not have to worry about burning out battery packs, or having a car with two powerplants — an engine and a motor — to maintain." He also agreed with General Motors' reasoning: For vehicles sold in the United States, hybrid technology makes the most sense in the biggest, gas-guzzling SUVs and other trucks.

On the other hand, according to Toyota's rebuttal writer [8], "Yes, a conventional car can be as clean as the Toyota Prius, and, yes, a diesel gets good fuel economy — in some cases as good as the Prius. Neither conventional gasoline nor diesel can do both, however. The Prius can and does. The Automotive News drivers said they recorded up to 48 mpg city and about 40 mpg highway with the Prius. That's much higher fuel economy for a car in the same size class, at a comparable price, with similar performance, and creating 90 percent cleaner emissions on regular gasoline available at any service station." The Toyota writer also states, "Overrated? Many motorists would disagree. The Prius has no particulate emissions. Even the cleanest diesel cars are not available in California or states adopting California's supplemental emission standards because they cannot meet the standards. In fact, non-California diesels are allowed 17.5 times more smog-forming emissions than a California Prius. And finally, the Prius battery is designed to last the life of the vehicle, and seven years of experience indicate that nickel-metal hydride batteries are exceptionally long-lived. In fact, all of the Prius' hybrid-related components, including the battery, are covered for 8 years/100,000 miles (and 10 years/150,000 miles in California-standard states)."

[**Editor's Note**. "They report — You decide." It looks like the Automotive News writer [7] was comparing "apples and oranges," so I tend to agree with the Toyota writer [8]].

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Mobile Radio

Javier Gozalvez, Senior Editor

3G News

AT&T Wireless started in July offering customers in Detroit, Phoenix, San Francisco and Seattle broadband mobile wireless services with its launch of the first commercially-available true 3G UMTS network in the United States. The company also deployed its UMTS technology in Dallas and San Diego later in September. The company said it now offers the fastest nationwide wireless data service with EDGE, and provides true 3G service in more U.S. markets than any other company. AT&T Wireless said its wireless broadband service provides customers with average wireless data speeds between 220 and 320kbps, with bursts up to 384kbps.

Sonera announced it will commercially launch, during October 2004, its UMTS network in 20 locations in Finland. The network will be further expanded according to demand. The data transmission rate of the network is 384kbps at its best. Sonera is also planning to introduce other technologies, such as EDGE.

T-Mobile has announced the launch of its UMTS data cards, combined with the extension of its Wi-Fi HotSpot access points across the UK. Initially, the data cards will give access to speeds of up to 128kbps although the company will progressively increase it to 384kbps. With the cards, customers can have seamless roaming between GPRS and 3G, depending on the coverage available.

Vodafone claims to be the first operator in the Netherlands to offer UMTS coverage to more than half of the Dutch population, in particular 55%. Vodafone expects to double the number of Dutch cities with Vodafone UMTS coverage before April 2005. By means of a unique Vodafone service, customers can determine whether the Vodafone

UMTS network is active within a particular area or at a specific location. Based on postal codes, Vodafone's Customer Services advisors can inform customers whether there is Vodafone UMTS coverage in a specific area.

Huawei has announced it has succeeded in making the first WCDMA call in Tunisia, which it claims is also the first WCDMA call in Africa. Through the execution of this project, Huawei is confident to provide an excellent WCDMA network to serve World Summit on the Information Society (WSIS) in 2005. For the 3G pilot network, Huawei will provide the entire end-to-end UMTS solution, including UMTS radio access network, core network, 3G mobile intelligent network, 3G mobile data service platform and even 3G handsets. For the UMTS system, Huawei will provide all the equipment based on 3GPP R4 protocol. The core network is backward compatible with 3GPP R99 and GSM. The coverage of the Huawei 3G network includes Tunis, Hammamet and the highway between Tunis and Hammamet.

Siemens together with Openwave Systems has supplied a 3G/UMTS Video Mailbox System and a Video Termination Gateway for the largest mobile operator in Portugal , TMN. The subscribers will be able to record personalized video and audio greetings and retrieve recorded video messages from missed callers with their video enabled handsets. Furthermore, the 3G/UMTS Video Termination Gateway allows real-time video communication between 3G/UMTS mobile terminals and fixed network terminals such as web cam-equipped PCs, 3G-324M video terminals, and PSTN video phones. Openwave provides the voice and video messaging solution that is the basis for the Video Mail System. This solution is an all-IP content based management and Mx infrastructure designed around the Voice XML standard.

Portelligent has released a study of UMTS handsets which indicates that handset designers have substantially reduced the average complexity and manufacturing costs of UMTS cellular phones over the past year. According to the firm, the first generation of UMTS handsets, which supported both GSM and WCDMA, were plagued by high system complexity and high cost when they were introduced in Europe and Asia in 2003, as well as by consumer complaints about product size and battery life. According to the findings of "product teardown" analyses conducted by Portelligent on 11 UMTS handsets introduced over the past 18 months, products that have appeared in the marketplace since the beginning of 2004 reduce the average number of electronic components found in the handsets by over 25%. The average number of high-value ICs in the 2004 products – which are a strong driver of overall manufacturing cost – has declined almost 50%, as handset makers achieve more integrated designs, and as semiconductor makers come to provide more mature chipsets and technology platforms for UMTS phones. Portelligent claims that while UMTS phones introduced in 2003 substantially exceeded WCDMA/FOMA and high-end CDMA2000 products in average IC count and total electronic component count, 2004 UMTS handsets bring overall component count to a much more comparable level, and have actually lowered average IC count below that of the feature-rich FOMA phones that NTT DoCoMo has introduced in Japan this year. The 11 handsets analyzed in Portelligent's UMTS study, which is entitled "The End of the Beginning: Progress in Technology, Design, and Manufacturing Cost in 3G UMTS Handsets", include models from NEC, Motorola, Nokia, Sony Ericsson, and LG.

Telstra has announced, in a network-sharing deal, that it will buy half of Hutchison's 3G Australia network. The two companies will each continue to own separate core networks, application and service platforms. Telstra is planning to commercially launch its 3G services next year using the entire network of more than 2000 base stations.

The UMTS Forum Chairman has indicated that 10 million people are already using 3G/UMTS networks and devices to access a wide range of services. By the end of this year, it is expected to see as many as 70 networks operating commercially. Mr Bienaimé said there has been an upturn in 3G/UMTS subscriber numbers since the early months of this year which coincides with a surge in network launch announcements during Q1 and Q2, plus a wider choice of attractively priced handsets from Asian, European and US manufacturers. Commercially available on 46 networks in 24 countries, 3G/UMTS is supported by a growing choice of WCDMA handsets and PC datacard products. More than 75 models have already been launched or announced.

NTT DoCoMo has announced that the number of subscribers to DoCoMo's 3G FOMA service surpassed the five million mark in July, reaching the figure in less time than it took to make the leap from three to four million subscribers at the end of this past May. DoCoMo attributes the rapid increase to the growing popularity of its latest 3G models in the 900i series, as well as its enhanced service area. FOMA service reached 99.7% of populated areas by the end of June. The number of indoor base stations has increased to about 2000, which includes all subway stations within both the Tokyo Metro and Toei subway networks. In addition, DoCoMo began fixed rate data packet transmission service for FOMA users on June 1, which offers users unlimited access to i-mode mobile internet service.

Hutchison Italy has announced it has 1.5million clients and expects to reach the year-end target of 2 million. The operator has also said it can now reach up to 38million Italians, that is two-thirds of the population.

Verizon Wireless has expanded its 3G wide-area BroadbandAccess network to include 14 major metropolitan areas and 24 airports across the United States. The BroadbandAccess network allows large enterprises, small-medium businesses and mobile professionals to conduct business anytime, anywhere in the BroadbandAccess-coverage area via a secure, true high-speed data connection with typical user download speeds of 300-500kbps. The BroadbandAccess network is based on CDMA2000 1xEV-DO. Verizon Wireless commercially launched the BroadbandAccess service in July 2004.

Eurotel Praha, a wireless operator in the Czech Republic, and Nortel Networks have launched what they claim is the industry's first CDMA2000 1xEV-DO network operating in the 450 MHz radio spectrum. The network, which was deployed across the Czech Republic in only four months, now offers advanced data services for broadband Internet access under the umbrella of "Eurotel Data Express". The infrastructure was deployed on top of Eurotel's existing hardware to maximize the operator's existing investment in 450 MHz spectrum and legacy network equipment.

VIVO and Motorola have launched a trial of Motorola's CDMA2000 1xEV-DO high-speed mobile broadband network solution on the carrier's network in Curitiba (Brazil). This 3G service will enable subscribers to experience high data rates – at peak speeds of up to 2.4 Megabits per second (Mbps). For purposes of the trial, Motorola upgraded existing Motorola Base Transceiver Subsystems with the addition of a new Multi-Channel CDMA Module to enable CDMA2000 1xEV-DO service.

Grupo Iusacell, a provider of cellular telephony products and services in Mexico, has commercially launched 3G CDMA2000 1X services and the first downloadable wireless products and services based on Qualcomm's BREW solution in Mexico.

Telecom Egypt and Huawei have announced the first successful CDMA2000 call at Fayoum province, a famous travel destination in Egypt. Huawei provided end to end CDMA 2000 equipments in the project, including CDMA2000 core networks, radio access networks as well as wireless terminals.

The CDMA Development Group (CDG) has announced that the number of CDMA2000 subscribers worldwide has exceeded 100 million. At the end of June, over 112 million people across all continents used the technology. CDMA2000 is used by 89 operators in 45 countries worldwide, with 36 more launches scheduled by the end of the year. More than 650 CDMA2000 devices have been introduced to the market.

KDDI has announced that the total number of subscribers to its CDMA2000 1X service exceeded 15million in July, just two years after its initial launch.

Alcatel has announced that the mobile network it has deployed for Orascom Télécom Algérie enables the operator to introduce the first broadband EDGE services ever provided on the African continent. In the framework of a supply contract, Alcatel deployed its end-to-end Evolium solution, a multistandard platform designed for GSM/GPRS/EDGE and 3G/UMTS networks.

3G Americas has announced that more than 100 operators in 63 countries from all regions of the world are in various stages of readiness for EDGE high-speed wireless data technology. Combined, these 108 operators represent hundreds of millions of customers in their current subscriber base. In addition to the 28 operators offering commercial 3G EDGE services to customers, there are 32 operators who are actively deploying EDGE, 33 planned EDGE deployments, 8 operators with EDGE-capable networks, and 7 other operators with EDGE networks reported in the trial phase. EDGE has been commercially launched in four Asian countries, 10 countries in Europe and the Middle East, and even Algeria, Africa.

In a new study, Analysys claims that some 3G operator strategies may damage the economic prospects for 3G at an early stage of its development. According to one of the authors, head-to-head competition with xDSL and WLAN could kill profitability. Instead, the firm recommends operators to find a more profitable way of co-existing with these alternative solutions. The firm also thinks that operators moving away from volume-based 3G charging are taking a big risk.

Technology News

The Ministry of Information Industry of China hosted a ceremony to launch the country's first developed chip based on TD-SCDMA standard. Spreadtrum Communication unveiled what they claim is the world's first GSM/GPRS/TD-SCDMA chipset, and announced that the product will be ready for mass production by the end of this year.

Samsung Electronics has unveiled the first-ever mobile phone with an internal hard disc drive. The V5400 is equipped with a 1-inch diagonal, 1.5GB hard disc drive that greatly expands the memory capacity of mobile phones from the conventional 100MB maximum capacity.

NTT DoCoMo has announced the development of the N900iL, a dual network 3G FOMA handset that runs on both FOMA and WLAN networks. The device may be used as a standard FOMA handset, as well as an in-house VoIP phone utilizing a company's internal WLAN network. As a result, users can prioritize standby for incoming calls from either FOMA or the WLAN network, or set the handset on dual mode to receive calls from both networks. The Japanese operator has also announced it will invest in Texas Instruments to jointly develop a single-chip LSI making FOMA 3G handsets compatible with both W-CDMA and GSM/GPRS networks. Currently, it is necessary to embed two chips in order to produce a W-CDMA and GSM/GPRS dual mode handset. Enhanced chipsets will also enable the upgrading of basic FOMA handset functions, such as longer standby-time.

Nortel has unveiled a new high-capacity, high-density base station, the GSM-UMTS Base Transceiver Station (BTS) 18000. The manufacturer claims that the BTS will allow operators to drive reduced operating costs by handling up to 50% more voice and data subscribers per BS compared to other commercial dual mode base stations currently available. The BTS 18000 will provide a common radio platform for GSM and UMTS that will be scalable and spectrally efficient, and will improve network capacity while limiting the need for the costly cell splitting often used to increase wireless network capacity. In addition, the BTS 18000 will be more compact because it will allow wireless operators to support both GSM and UMTS without needing a separate cabinet for UMTS. Wireless service providers will be able to enhance BTS 18000 to support HSDPA without hardware upgrades.

Nokia has announced the development of Nokia MetroSite 50 BTS for the US market. Nokia claims it is the world's smallest three-sector WCDMA base station whose size and high-power radio frequency performance will offer flexible deployment options in large and small coverage areas. The flexibility offered by the BS is expected to yield up to 30% in site and deployment cost savings.

Fujitsu Microelectronics has introduced a new chipset for the high-sensitivity GPS/AGPS receivers. According to the manufacturer, the chipset achieves the industry's highest levels of sensitivity, accuracy and Time-to-First-Fix (TTFF) with low power and a small PCB footprint. The chipset supports GPS L-band C/A code and is capable of operating in both "autonomous GPS/standalone" mode and "assisted GPS" mode. It also supports leading air interfaces, including UMTS/WCDMA, GSM/GPRS, PDC and CDMA.

Nokia has announced that the Variable-rate Multimode Wideband speech codec (VMR-WB), developed and characterized by 3GPP2/TIA, is ready for large-scale deployment. According to Nokia, it is the first speech codec that is fully interoperable with 3GPP/AMR-WB, the standard in GSM and WCDMA networks. The VMR-WB codec outperforms the existing wireless and wireline codecs operating at the same data rates and can be used in a variety of circuit-switched or packet-switched multimedia applications. The algorithmic specification of VMR-WB standard has been published by 3GPP2 and TIA as 3GPP2 C.S0052-0 v1.0 and TIA-1016, respectively, and its software will be available through these organizations and Nokia.

Intel has disclosed key technical details of its upcoming WiMAX product, code named "Rosedale". The product is expected to be the first "system-on-a-chip" design for cost-effective customer premise equipment (CPE) that supports IEEE 802.16-2004 (previously known as IEEE 802.16REVd). IEEE 802.16-2004, also known as WiMAX, is an emerging wireless standard that promises to provide

broadband connectivity at DSL speeds across long distances. ntel has begun sending sample Rosedale product to key customers. Rosedale will include the 802.16-2004 MAC and OFDM PHY, an integrated 10/100 MAC, inline security processing and a TDM controller interface which enables applications such as broadband Internet streaming data and voice. WiMAX Forum, an industry group chartered to test and certify interoperability among WiMAX products, is expected to hold initial interoperability testing and certification programs in 2005.

picoChip has announced the availability of complete software implementations for HSDPA picocells and 802.16 (WiMAX) basestations, the PC8218 and PC8520 respectively. Both "off the shelf" systems run on the company's PC102 picoArray DSP. The picoChip PC8520 WiMAX basestation solution provides a software-defined implementation of the 802.16-2004 PHY, for the 256OFDM mode with "carrier-class" reliability and performance. The PC8520 enables basestations to be WiMAX-certified. The software upgrade to 802.16e for mobility, including scalable PHY and advanced FEC, will be available next year. The PC8218 HSDPA picocell replaces the company's previous reference design by integrating the complex Iub interface, significantly reducing system BoM and simplifying integration.

NMS Communications has announced it is working with Lucent Technologies to design and build an enhanced optical voice processor for wireless network operators building 3G networks. Advanced signal processing will improve call clarity and quality. NMS expects initial commercial deployment within a year.

Orange Switzerland has launched Mobi-Click, a mobile phone equipped with only three buttons. The Swiss-produced Mobi-Click is aimed at people looking for an easy-to-use mobile phone just to make calls, such as the elderly or disabled. The new handset allows such people to contact their family without having to dial a number. The Mobi-Click is a plain mobile phone with three large buttons; for each one of the buttons, the most important numbers are stored.

The Mobi-Click phone has only three buttons

ntl's Broadcast division and O2 have announced the UK's first usability trial of multi-channel television to mobile phones, beginning in spring 2005. From nine broadcast transmitters covering 120 square km around Oxford, the trial will see 500 O2 customers provided with a multimedia mobile phone with a built-in digital TV receiver. This will allow the participants to receive a line-up of 16 TV channels. To carry out the trial in the UK, ntl has joined forces with O2, Sony and Nokia, that will make available their prototype DVB-H receiver devices. ntl will develop the TV channel portfolio and will design, build and operate the transmission network. The trial will use the DVB-H broadcast transmission standard for handheld devices, which is an efficient 'one-to-many' method of delivering content in a way that complements the functionality of 3G.

Nokia and NEC have successfully completed the first phase interoperability testing between the two companies' IP Multimedia Subsystems (IMS). The testing program verified the functionality of major IMS features over an IP network connecting Europe and Japan. During the tests, Nokia and NEC established sessions for voice over IP as well as transferred instant messages between test terminals. IMS enables both mobile and fixed devices to establish IP sessions between each other. Also Push to talk over Cellular, the voice service for one-on-one and one-to-group communications, will work over IMS. Standardized in 3GPP Release 5, IMS is designed to allow service access and interoperability between operators and vendors. The trials are also being used to look at issues related to roaming at the service level.

Racal Instruments Wireless Solutions (RIWS) claims to be the first test equipment manufacturer to have approved test cases for use in the UMTS 1900 MHz 'FDD Band II'. The test cases have been validated by the Validation Competence Center of CETECOM, in Essen, and include Inter-System Handover between 1900 MHz UMTS and 1900 MHz GSM. The 6401 AIME/CT system provides the capability to run the standard UMTS protocol conformance tests, as defined in 3GPP TS 34.123 and implemented in TTCN.

Radioplan has announced the release of WiNeS 3.1, which it claims is the world's first commercial simulation and optimisation toolset for the HSDPA standard, considered the evolution of WCDMA.

In-flight wireless services

Qualcomm and American Airlines have successfully demonstrated in-cabin voice communications using commercially available CDMA mobile phones on a commercial American Airlines aircraft. Through the use of an in-cabin 3G "picocell" network, passengers on the test flight were able to place and receive calls. The proof-of-concept demonstration flight originated out of the Dallas/Fort Worth International Airport. During the approximate two-hour flight, passengers were able to place and receive phone calls and text messages on their mobile phones. A small in-cabin CDMA cellular base station on the plane, that uses standard cellular communications, was connected to the worldwide terrestrial phone network by an air-to-ground Globalstar satellite link.

Airbus has also successfully completed an in-flight trial using GSM technology, developed by Airbus in conjunction with Icarelink. During the trial, calls and text messages were sent and received during the flight without interfering with the plane's navigation systems. The calls were routed through a picocell to a Globalstar satellite communications network and then to a ground-based wireless network. The companies also trialled Bluetooth, Wi-Fi and WCDMA. Moreover, a medical emergency was simulated to show how the system performed when some traffic has to be prioritised. Airbus has said it is planning to put in-flight mobile phone technology on its aircrafts by 2006.

Malaysia Airlines will soon allow its passengers to send and receive short text messages and short e-mails through its In-flight Entertainment system. The company has decided to equip its Boeing aircrafts with SITA's AIRCOM SMS facility.

The Association of Flight Attendants (AFA) is joining forces with industry groups to develop and recommend standard practices to manage the use of wireless devices on aircraft in flight. Previously, the Consumer Electronics Association (CEA) said it is working to enable mobile phone users to use their phones during the flights.

According to a research study conducted by Telenor and ARINC at the London Heathrow and Gatwick airports, nearly half of all international business fliers would prefer to travel on airlines that allow the use of mobile phones in flight. The two companies are marketing an inflight GSM service.

Research News

NTT DoCoMo has announced the joint development of a prototype micro fuel cell for 3G FOMA handsets. The prototype, manufactured by Fujitsu Laboratories, is expected to greatly extend FOMA handset usage time once it goes into commercial production. The micro fuel cell is aimed at meeting user demands for more convenient handsets with greater power capacity, as well as reduced environmental impact. The micro fuel cell is a standalone device shaped like a cradle for recharging handsets. It generates electric power by combining hydrogen and cheap, environmentally harmless methanol to produce a chemical reaction. Hydrogen ions are extracted from the air via a layer sandwiched between positive and negative electrodes. The prototype has the same basic specifications of other FOMA handset rechargers and will be compatible with all FOMA handsets. Further development of the prototype is expected to be completed by the end of fiscal 2005.

Micro fuel cell for 3G FOMA handsets

mPhase Technologies and Lucent Technologies have announced a major milestone for future commercialization of a nanotechnology-based battery. Lab tests, which have been replicated, proves it is possible to fabricate nanotech-based batteries, which can store and generate electric current. The prototype battery is based on a Bell Labs discovery that liquid droplets of electrolyte will stay in a dormant state atop microscopic structures called "nanograss" until stimulated to flow, thereby triggering a reaction producing electricity. The experiment proved that this super-hydrophobic effect of liquids can permit precise control and activation of the batteries on demand.

KDDI has announced an agreement with Toshiba and Hitachi to cooperate on research to develop a compact fuel cell battery that can be used in mobile phones by the end of 2005. The research will cover areas such as miniaturization, ease of use and all technical considerations required for incorporating the batteries into mobile phones. The plans are to complete an external, battery-charger-type model within 2004 and a complete mobile phone with built-in model by the end of the 205 fiscal year.

The National Institute of Standards and Technology (NIST) has awarded Carbon Nanotechnologies, Motorola and Johnson Matthey Fuel Cells a $3.6 million grant to develop "free standing" carbon nanotube electrodes for micro-fuel cells in order to meet the ever-growing demand for more power and longer run times in portable microelectronics.

Vodafone Netherlands is currently testing a handy charger equipped with solar cells. The solar charger is a flat box that contains a small solar collector. To be charged, the box has to be unfolded, put into daylight and connected to the mobile phone or PDA.

Strategy Analytics has predicted that the market for battery cells will exceed $9billion by 2010. The firm claims that the demand for small form factor fuel cells will be disappointing and that the development of Lithium-sulfur batteries promises to double the capacity of traditional rechargeable batteries. According to Strategy Analytics, the development of the fuel cell market will be inhibited by the lack of a suitable supply chain and restrictions on the carriage of methanol on public aircrafts.

At the "Mobile Internet 2010" forum held by the German Ministry of Education and Research, Siemens presented a test system where videos and music as well as a Microsoft NetMeeting conference were transmitted in wireless mode at data rates of up to 360Mbps. To also achieve these peak data rates for larger coverage areas, Siemens claims it is the first company to test a combination of orthogonal frequency division multiplexing (OFDM) and the so-called multi-hop technology, a new infrastructure concept. The system was already tested successfully in a field trial in the center of Munich. The multi-hop concept can increase the signal coverage area considerably. Wireless but fixed multi-hop stations — a combination of base station, repeater and router — forward the signal from cell to cell, also around obstacles, down to the terminal device when the direct link between base station and mobile terminal is interrupted. To make the high-frequency signals more resistant to interference, Siemens deploys OFDM.

Motorola has claimed that, by combining results from field experiments and research conducted by Motorola Labs, it has proven existing OFDM technology can support high-speed mobile networks with a peak downlink speed of up to 300Mbps. Motorola Labs recently completed a series of mobile wide area broadband wireless field experiments using OFDM on a 20MHz bandwidth channel with multiple antenna handheld devices. Applying data from the field experiments in laboratory tests, Motorola Labs validated that a 20MHz mobile OFDM channel can support peak uncoded channel data rates of up to 300Mbps. The field tests were conducted in the greater Chicago area in both urban and suburban environments. In the field tests Motorola Labs attained data throughputs exceeding 20Mbps with a latency of just 25milliseconds while simultaneously demonstrating real-time applications and travelling at typical highway speeds (in excess of 100km/h or 62mph).

Flarion Technologies has announced that T-Mobile has deployed a trial of Flarion's system for mobile broadband services in the Hague (Netherlands). T-Mobile has been testing FLASH-OFDM since 2003 and will now collect data on usage and customer behaviour. During the trial, users will experience a mobile data service of around 1Mbps capable of bursting to 3.2Mbps in the downlink and 30-50kbps in the uplink, bursting to 90kbps.

The National Taiwan University (NTU) is collaborating with eASPNet Taiwan and Nortel Networks to commence trials of a new Nortel Networks Wireless Mesh architecture designed to extend the reach of WLAN technology. This new architecture enables wireless broadband connectivity for enterprises and end-users with indoor and outdoor access. Nortel Networks Wireless Mesh Network solution uses wireless links to connect the access points, allowing enterprises or service providers to install WLANs with a minimal amount of Ethernet cabling or other backhaul facilities in areas where network limitations make it cost -prohibitive to use traditional wired access points. The company claims that this innovative approach can drastically reduce the complexity and cost of deploying a traditional WLAN network. Nortel Networks and NTU have already demonstrated advanced services over the Wireless Mesh Network solution, including video streaming, Wi-Fi voice over IP and

seamless hand-over while driving at speeds of 50km/h. The Wireless Mesh Network solution incorporates 'auto discovery' and 'self healing' algorithms to simplify deployment by enabling installation in any location where power is available and reduces services outages by optimizing radio link communications and minimizing interference. In addition, the self-organizing nature of this architecture minimizes the need for Radio Frequency engineering and commissioning, which can significantly increase WLAN coverage.

US Mobile Market

The Federal Communications Commission (FCC) has provided an additional twenty megahertz of spectrum that can be used to offer a variety of broadband and advanced wireless services (AWS), potentially including 3G wireless services. The Commission allocated and paired five-megahertz blocks of spectrum at 1915-1920 MHz with 1995-2000 MHz, and 2020-2025 MHz with 2175-2180 MHz for AWS use. The Commission redesignated the 1915-1920 MHz band for AWS from Unlicensed Personal Communications Services (UPCS) and pairs this five-megahertz block of spectrum with the five-megahertz block at 1995-2000 MHz (which was previously allocated for the Mobile Satellite Service (MSS)). An additional ten megahertz of spectrum at 2020-2025 MHz and 2175-2180 MHz – previously allocated for MSS – is to be made available as paired five-megahertz spectrum blocks. The Commission concluded that pairing the bands in this manner promotes a more efficient use of the spectrum and complements adjacent band operations. The Commission also modified Part 15 of its rules with respect to unlicensed PCS operations in the 1920-1930 MHz band to provide additional flexibility for users of the band to offer both voice and data services using a wider variety of technologies.

The FCC has adopted its Ninth Annual Report to Congress on the state of competition in the commercial wireless (CMRS) industry. The Commission found that 97% of the total U.S. population lives in a county with access to 3 or more different operators offering mobile telephone service, up from 95% in the previous year, and up from 88% in 2000, the first year for which these statistics were kept. The Commission found somewhat larger increases in the percentage of the U.S. population living in a county with access to 4 or more, 5 or more, 6 or more, and 7 or more different mobile telephone operators in the past year. The FCC noted that average monthly churn rates remain at about 1.5 to 3.5% per month and that the advent of wireless local number portability in November 2003 has lowered consumer switching costs. In the 12 months ending December 2003, the US mobile telephony sector increased subscribership from 141.8 million to 160.6 million, raising the nationwide penetration rate to approximately 54% of the population. Average minutes of use per subscriber per month increased to more than 500 minutes by the end of 2003 from 427 minutes in 2002 and 255 minutes in 2000.

The FCC has adopted a general prohibition on sending commercial messages to any address referencing an Internet domain associated with wireless subscriber messaging services. To assist the senders of such messages in identifying those subscribers, the Commission required that commercial mobile radio service (CMRS) providers submit those domain names to the Commission for inclusion in a list that will be made publicly available. No individual subscriber addresses will be collected or included on this list.

MeshNetworks has announced that it has been granted a new experimental license from the FCC to deploy a number of fixed and mobile experimental mesh networks. This experimental license allows the company to conduct nationwide trials of new products and technologies at 2.5 GHz and in the newly created 4.9 GHz public safety band. The FCC decided to dedicate the 4.9 GHz band exclusively for use by the public safety community. MeshNetworks solutions leverage battlefield networking technology originally developed for the U.S. military under DARPA directed programs. Specifically, the grant allows MeshNetworks to deploy a total of 1000 nodes, with a maximum of 200 per demonstration network. These quantities will enable the company to deploy metro scale demonstration networks.

Cingular Wireless has been awarded a contract by the National Communications System (NCS) to provide Wireless Priority Service (WPS) to the country's authorized emergency response personnel. Total network deployment will be complete by the summer of 2005. WPS provides authorized Federal, State, and local government leaders and critical private sector leaders and decision makers with priority wireless service during times of emergency. In times of congestion, authorized users are moved to the front of the queue, greatly increasing their chances of call completion. At the same time, WPS is designed to have a negligible impact on everyday cellular users, providing priority service to vital decision makers without restricting the public's ability to gain access to those same networks. WPS does not enable users to preempt existing calls or to monopolize cellular services.

Cingular Wireless, AT&T Wireless and Triton PCS have signed a definitive agreement that - contingent on closing of Cingular's acquisition of AT&T Wireless - would give Cingular expanded wireless service in Virginia and Triton PCS added coverage in North Carolina as well as entry into Puerto Rico and the U.S. Virgin Islands. The companies expect the Cingular/AT&T Wireless merger to close in 2004. Leap Wireless has signed an agreement to acquire a wireless operating license in Fresno (California). The 30MHz license covers approximately 950,000 potential customers. MetroPCS has purchased a 20MHz C block license from US Cellular in Daytona Beach. Centennial Communications has announced the purchase of 10MHz of spectrum from AT&T Wireless. The spectrum covers contiguous markets in Michigan and Indiana.

Verizon Wireless, a CDMA operator, has launched a Samsung handset (a790) that enables their subscribers to roam onto GSM networks overseas. The Samsung handset incorporates GSM and CDMA technology using Qualcomm's MSM6300 chipset solution, designed to allow global roaming between GSM and CDMA2000 1X networks.

The city of Philadelphia has announced plans to launch a citywide wireless network. The intention is to mount up to 16 Wi-Fi routers per square mile on streetlights. Boston and Madison are said to be considering similar options.

Spectrum Licenses

Brazil has announced it has sold 2 out of 6 mobile phone licenses, for less than 25% of the total in reserve prices for the six licenses. Claro and Telemig Cellular acquired the licenses. For the other 4 licenses there were no bidders.

Romania has launched the sale of four 3G licenses. The government is expected to select the winners for the 15-year licenses in the first half of November. The licenses are being offered for about _35million each. Romania, with a population of 21.5million, has four mobile operators that offer service to about 8.3million users.

Canada has announced its decision to rescind the mobile spectrum cap policy that limited the amount of radio spectrum that cellular operators could hold. The mobile spectrum cap policy was introduced in 1995 to encourage innovation and help the entrance of new operators. The Ministry of Industry will continue to manage the licensing of spectrum resources.

According to a new report from Analysys ('Spectrum Trading and Liberalisation'), the introduction of spectrum trading and the liberalisation of the use of specific spectrum bands will play a key part in creating a more dynamic, competitive and innovative wireless service market. The firm said that growing numbers of countries have already adopted, or are in the direction to do so, regimes that will allow operators to obtain tradable rights in radio spectrum in an attempt to increase efficiency and innovation.

Industry Forecasts and Surveys.

According to Gartner, worldwide mobile phone sales surpassed 156.4 million units in the second quarter of 2004, a 35% increase from the second quarter of 2003. On a regional basis, the Western European market is being driven by consumers who got their first mobile phones in 2000 and 2001, and now they're upgrading to smaller color screen phones with built in cameras that have become available at much lower prices. Brazil continued to be the driving force in Latin America, although Mexico also contributed strong sales in the region. In North America, replacement sales were high. More than 300 million mobile phones have been sold in the first half of 2004, and Gartner analysts have projected year-end sales to reach approximately 620 million units. On the other hand, IDC said that worldwide mobile phone shipments in the second quarter of 2004 increased 2.5% over the first quarter and rose 36.7% year-over-year to 163.7million units. In the vendors ranking, Nokia is still first (with a 27.7% market share), followed by Motorola (14.7%), Samsung (13.9%), Siemens (6.4%), Sony Ericsson (6.4%) and LG (6.1%). In a different report, IDC said that the worldwide handheld devices shipments increased 3.2% sequentiall and dropped 2.2% year-over-year in 2Q04 to 2.2million units. On the other hand, Canalys reported that the mobile device market in EMEA experienced a 52% increase in 2Q04 compared to the same period in 2003.

ABI Research has forecasted that during 2004 the worldwide base station new deployments will increase by more than one third over 2003 but will decline, in 2005, by approximately one fifth from 2004. According to In-Stat/MDR, 2004 worldwide cellular base station revenue will be down 14.4% from 2003 due partly to price pressures and an increase in spectrum efficiency. However, the firm said that the actual number of base stations is forecasted to increase slightly, from 329,483 in 2003 to 333,876 in 2004. In-Stat/MDR also expects that by 2008, WCDMA will represent 23.1% of deployed base stations worldwide and GSM 61.5%. Dell'Oro has said that total mobility infrastructure revenues, including sales of GSM/GPRS/EDEG, TDMA, CDMA and WCDMA equipment has reached $9billion in the second quarter of 2004, which represents an increase of 37% compared with the same period in 2003. GSM/GPRS/EDGE network sales accounted for 60% of the net increase. Although the market for WCDMA infrastructure equipment fell 19% over the same period of time, the firm expects this market to grow in excess of 50% in 2004.

Strategy Analytics has estimated, in its Cellular Data Forecast model (2004-2009), that global revenues from mobile data will grow from around $61billion this year to just over $189billion in 2009, with person-to-person messaging representing 48% of the total. A new study by the ARC Group predicts that by 2009 wireless data access revenues, from cellular networks and hotspots, will have grown to $130billion worldwide. The firm expects that 72% of these revenues will come from wide-area networks. In terms of Wi-Fi hotspots, the number will grow to 134,700 by 2006. North America is expected to have more than 61million hotspot users by 2009. A study from Mobinet has reported that 41% of global wireless phone users expect to be regular or heavy users of data services by 2005. The more frequent reasons for justifying not using such services today were cost (35%), security and privacy concerns (22%), and slow network access (18%).

A study from the Yankee Group predicts that peer-to-peer (P2P) multimedia messaging service will generate more revenue than P2P short message service by 2008. Frost & Sullivan expects a significant drop in the contribution of SMS toward mobile data revenues from 90% in 2003 to 40% in 2008. The firm expects that MMS will achieve a 65% penetration rate in 2008, which will create 210million active users and $10billion in revenue for mobile operators. Meanwhile, MMS traffic in Telia's mobile network in Sweden increased sharply during July (most popular vacation month) with more than 1.6million MMS sent, which represents twice the number sent in June. The Mobile Data Association (MDA) has said that the volume of person-to-person text messages sent in August in the UK rose 29% on the year to 2.2billion. The MDA said that 79 million texts were sent on the 26th of August after UK exam results were published.

A new report from Strategy Analytics predicts that over the next 5 years, there will be an expected six-fold growth in the mobile games market, with downloadable games generating 82% of this _6.65billion market. In terms of Java and BREW capable handsets, the number will rise from 186million units this year to over 1billion in 2009. The firm also expects the number of downloadable games' users to grow from 32million this year to 220million in 2009. In a different report, In-Stat/MDR estimates that by 2009, mobile gaming services in the US will generate $1.8billion annually, which represents 4.4% of total wireless data revenues.

The Pierz Group estimates that the addition of mobile numbers to the US directory assistance/enquiry database could translate to a revenue of nearly $2billion by 2008. According to the firm, 53% of all telephone subscribers are unreachable through DA/DQ services, with 97% of mobile phones unlisted.

In a new survey, conducted by Wavelink Corporation, 79% of the survey respondents said they plan to pilot or implement an RFID solution. Of this number, 22% have already implemented a pilot RFID program, while 42% will implement it in the next 12 months. The remaining 21% of respondents plan to implement an RFID solution within 12 to 24 months. The top reasons cited for implementing RFID included improving the ability to track goods, meeting customer requirements and receiving greater efficiencies in shipping and receiving. The survey also revealed a critical need to address key concerns associated with RFID, including high cost, an early, untested market and lack of sophisticated software to integrate RFID with other business applications like supply chain management and ERP systems.

According to a report from VDC, the US military is the largest proponent and purchase of software-defined radio equipment. The firm expect SDR shipment to the US mili-

tary to reach more than $1.7billion in 2007, representing a compound annual growth rate of 48.4% between 2003 and 2007. The Department of Defense's JRTS program accounts for most of the SDR purchase.

A new report from Parks Associates predicts that, by the end of 2009, there will be more than 7million subscribers worldwide using broadband wireless services based on 802.16REVd technology. The firm also said that the market is unlikely to see volume commercial deployment until 2006.

The CDMA Development Group (CDG) has reported that the CDMA industry added nearly 10.5 million subscribers in 2Q 2004, reaching 212.5 million users worldwide, and in the first six months of 2004, the subscriber base grew by a record 24 million users. From 2002 through the first half of 2004, the CDMA subscriber base increased by an average of 30% per year versus 21% for the total wireless market.

3G Americas has reported that customers in the Western Hemisphere are quickly adopting GSM wireless technology, making it the number one choice of new cell phone customers. In Latin America, the total number of GSM customers reached 36 million, surpassing the number of CDMA customers by 1.6 million as of June 2004. Globally, GSM accounted for 82% of new digital wireless customers representing 57.8 million of the 70.3 million net subscribers added in the second quarter. In the U.S. and Canada alone, GSM annual growth was nearly 85%, four times the growth rate of other mobile technologies.

Wireless LAN

Alcatel has deployed for ONO an end-to-end Wi-Fi solution for the Royal Nautical Club at the Valencia seaport (Spain). Valencia will be hosting the 32nd America's Cup in 2007. This solution offers a fiber and radio supported broadband connection, placing the Royal Nautical Club of Valencia in the vanguard of telecommunication technologies. Alcatel's Wi-Fi outdoor solution for the Valencia seaport provides broadband connections to more than 300 users simultaneously and places particular emphasis on security issues and access management. In order to fit out Wi-Fi access point systems, a mixed design with fiber-Ethernet converters has been developed.

Siemens, working in collaboration with WLAN software vendor Garderos and Cisco Systems, has built an extensive network of WLANs for Greece's Vodafone–Panafon, in which WLAN services provide a seamless roaming experience across five countries and which also offers centralized, cashless billing. Vodafone customers in Greece, France, Italy, Switzerland and Portugal can now take advantage of fast Internet access at all hotspots in the network system and pay conveniently via their regular telephone bill. Siemens integrated the WLAN solution into the infrastructure of the Greek mobile network. In this context, Cisco delivered its IP-based Service Selection Gateway (SSG), while Garderos software was integrated into the "Siemens Wireless Integration Platform" in order to provide the customers of this Greek provider with extremely flexible billing options.

Ericsson has announced the supply of over 6,000-access points to The Cloud. The access points will be integrated into different public locations around UK. The Cloud operates a multi service-provider Wi-Fi platform, which allows providers such as ISPs, mobile operators and cable companies to offer a fully branded WLAN experience to their customers. The Cloud offers national WLAN coverage with more than 4,300 hotspot locations and is opening more than 100 new locations each week.

NTT DoCoMo has announced that it will extend its international roaming service to 33 countries for its public WLAN service, under an agreement with iPass, a U.S.-based provider of connectivity services. The 33 countries span North and South America, Europe, Asia, Oceania, and Africa. Users will be able to use WLAN services available at more than 3,000 international high-profile hotels (24 countries) and passenger terminals at 82 international airports (17 countries).

According to Dell'Oro Group, enterprise LAN revenue increased to $204million during the second quarter, with the growth primarily due to sales of access points with WLAN switch/server appliances. In the later market, Symbol Technologies appears as the leader increasing its market share by 20 percentage points. The firm also predicts that sales of WLAN products will grow 20% in 2004 to $2.1billion. Dell'Oro expects enterprise-class access point shipments to increase by 75% in 2004, growing at an average annual rate of 47% through 2008. In a different study, IDC has reported that the EMEA WLAN market declined by 10% in the second quarter of 2004 but is up 188% year over year, reaching a total end-user revenue of $320million. The firm has said that price erosion and lower shipments of access points and add-on clients are the main cause for the revenue decline. A new study by the Radicati Group predicts that by year-end 2004 there will be 39million WLAN consumer and enterprise users. The firm expects that, by 2008, there will be 120million WLAN users and that the worldwide revenue for WLAN Infrastructure, Security and Management will reach $8.6billion. In a corporate survey conducted by the Group, 40% of the companies that have deployed WLAN said that ease-of-use was the best product feature against a 30% stating that it was its roaming capabilities. In-Stat/MDR expects WLAN equipment revenues in China to increase at a near 33% CAGR from about $54million in 2004 to almost $160million by 2008. The research firm also said that foreign equipment providers have a combined 70% share of overall revenue.

Ultra Wideband

Pulse~LINK has conducted the first public demonstrations of its RF ASIC capable of simultaneously transmitting UWB communications wirelessly, over cable television networks and electrical wiring, as well as narrowband communications such as WiFi and Bluetooth. The simultaneous transmission of each of these communications types from a common chipset is made possible by Pulse~LINK's latest digital-to-analog converter (DAC) 0.18 micron silicon germanium test chip. With performance tested up to 20 Giga-samples per second, the DAC can perform direct digital synthesis of any UWB pulse shape or narrowband carrier between DC and 10Ghz of spectrum. Pulse~LINK demonstrated its DAC generating pulses shaped specifically for UWB communications across in-home electrical wiring, UWB communications on a 750 Mhz cable television network, wireless UWB communications covering multiple modulation techniques, and narrowband carriers at 2.4Ghz that is used for WiFi 802.11b/g and Bluetooth, as well as at 5.1 to 5.3 Ghz that is used for WiFi 802.11a. Pulse~LINK has also conducted public demonstrations of multiple streams of high definition television being delivered via Pulse~LINK's UWB cable, power line, and wireless technologies. Pulse~LINK's UWB cable demonstration was conducted utilizing a miniature version of a metropolitan area hybrid fiber coax infrastructure featuring multiple streams of standard cable television feeds operating simultaneously in the presence of UWB enabled HDTV content.

Freescale Semiconductor has partnered with several companies in Taiwan for the development of UWB into consumer electronics. In particular, it is working with Universal Scientific Industrial to develop a UWB-enabled 1394 module intended for use in wireless LCD televisions and home media services. With Gemtek, it is working to deliver a UWB-enabled mini-PCI module for video and data streaming applications. GlobalSun Technology is also working with Freescale to create a mini-PCI module.

In-Stat/MDR has projected that UWB node/chipset shipments will experience an emerging market compound annual growth rate of over 400% from 2005 to 2008. According to the firm, UWB-based products will only start to roll out in 2005, with a small level of shipments based on proprietary chipsets from Freescale and General Atomics. In-Stat/MDR also claims that, as UWB rolls out, it faces no serious competing technologies, since alternatives only offer slower ways of accomplishing data transfers, with speeds that are 1% to 10% of a 480Mbps UWB solution.

Forums and Industry Alliances

Fourteen service providers, infrastructure suppliers, and handset manufacturers in the wireless industry have published a set of open specifications for extending mobile voice and data services over Wireless LANs. With the UMA specifications, service providers can look to deploy interoperable solutions that enable subscribers to roam and handover seamlessly between cellular networks and public and private WLANs using dual-mode mobile handsets. More information about UMA technology, as well as access to the UMA specifications, is available through the UMA technology website (www.umatechnology.org).

Motorola, NEC, Nokia, Siemens and Sony Ericsson have announced their co-operation in the Mobile Broadcast Services work, started under Open Mobile Alliance, OMA. The charter of the work is to specify the enablers needed to bring broadcast services to mobile devices and to open up the market for new exciting mobile services and terminals. A likely spearhead service of mobile broadcast is mobile phone TV. In general, mobile broadcast will enable cost efficient mobile mass delivery of any multimedia content.

A Fixed-Mobile Convergence Alliance (FMCA) has been formed to accelerate the development of fixed-mobile convergence products and services. The founding members of the alliance include Brasil Telecom, British Telecom, Korea Telecom, NTT, Rogers Wireless and Swisscom.

The World Wide Web Consurtium (W3C) and the Open Mobile Alliance (OMA) have announced a Memorandum of Understanding (MoU) to collaborate on specifications for mobile access to the web. OMA develops interoperable mobile data service enablers. W3C develops recommendations including XHTML Basic, SMIL and mobile SVG.

The Mobile Marketing Association has announced the formation of an anti-spam committee. The committee will research the merits of a national preference and privacy database designed to ensure a spam-free mobile experience. The system is expected to be open, flexible and optional. The association has already released in 2003 a Code of Conduct.

Wireless, PMR and Public Safety.

MeshNetworks and Motorola have signed an agreement enabling Motorola to distribute the MeshNetworks Enabled Architecture (MEA) mobile ad hoc networking solution. The MEA solution's self-forming, self-healing mobile broadband networking and precision position-location solutions will be offered as part of Motorola's advanced wireless broadband data portfolio for enterprise, utility and public safety. By leveraging MeshNetworks technologies, users equipped with a mobile computer, a PDA, or other Motorola-powered data device are able to join with other users to create an ad hoc broadband network capable of operating under harsh conditions, even in the absence of existing radio infrastructure. Every mesh-enabled radio serves as a router/repeater for every other radio - automatically extending the range and robustness of the network. Broadband data, video and asset tracking are available on scene, even if a natural or manmade disaster has destroyed the surrounding radio network. MEA network products operate in the unlicensed 2.4 GHz band and leverage patented radio technology to mitigate intentional and unintentional interference from other devices within the band.

Motorola has launched its new Mobile Automated Fingerprint Identification System (Mobile AFIS). The solution includes advanced tools previously available only in forensics laboratories and enables public safety officials to rapidly establish the identity of an individual by providing remote access to fingerprints, facial images and criminal history records.

Nokia will be providing a TETRA system to The Societé des Autoroutes Paris-Rhin-Rhône, which operates motorways across central eastern France. The system features the Nokia TETRA Neat architecture, tailored for a motorways type of network. Nokia has also announced the availability of the THR880i hand portable radio, which incorporates a GPS receiver and enables radio users to send their coordinates to a predefined address simply by pressing a button. The device will be available in three frequency bands (380, 410 and 800MHz bands).

Alcatel will install a TETRA network for the Parisian public transport agency (RATP), one of the world's largest. The network will cover Paris' extensive Metro, express line and bus system. The TETRA network to be deployed by Alcatel comprises six Nokia TETRA switches and around 500 TETRA base stations, as well as operator consoles developed by Alcatel using Nokia's open interfaces, and Alcatel's mass transit-specific applications. The network will enable mobile voice and data connectivity for over 10,000 personnel.

Belgocontrol, the Belgian air navigation service provider, has selected Motorola to supply a state of the art TETRA system. The Motorola Dimetra IP system will consist of three sites covering Brussels National Airport. It will be used by approximately 1,000 users for both voice and data aiding communication between different organizations and departments in the airport. The US manufacturer has also announced it will be providing a TETRA system to the Aeronautical Radio of Thailand (AEROTHAI) for the New Bangkok International Airport. The 800 MHz TETRA system comprises 3 base sites with a total of 28 base radios, and more than 2300 portable and mobile radios to support the communications requirements of the new airport. Other new networks to be provided by Motorola include the Chengdu Emergency Response Centre and the first line of Tianjin Metro. The network for the Chengdu Emergency Response Centre, which includes 8 base stations and 10,000 subscriber units, will be integrated with the Emergency Response Centre's existing analog system.

NICE Systems and Motorola have announced the availability of a critical new solution for ASTRO 25 Trunked Radio Systems. The logging solution provides digital voice and data recording of transmissions enabling public safety and governmental agencies to record and store the complete history of an incident as it is happening. Through a collabo-

rative effort, NICE has created a voice recording for Motorola's ASTRO 25 Trunked Radio Systems that will enable mission critical agencies to search for and replay telephone calls and radio transmissions, including radio and talkgroup identification and aliases.

Other News

Cosmote, a Greek mobile operator, has announced that its Olympic Network performance resulted in a 100% success rate in the coverage of all Cosmote mobile traffic of the Olympic Games, with more than 34.1 million minutes, averaging 2 million minutes a day from the 13th until the 29th of August. During the above mentioned period, more than 32 million calls were made inside and around the Olympic Venues. It is worth mentioning that in the Athens Olympic Complex itself, for which Cosmote increased network capacity by 15 times, the number of calls surpassed 5.7 million. During the Olympic Games, the number of text messages (SMS) exchanged exceeded 100 million. Cosmote's GPRS network carried 27 million Kbytes of data volume. In total, approximately 600 million calls were successfully made on Cosmote's network during the Olympic Games. Vodafone also announced that more than 115 million SMSs were sent, during the event, through its network. The company's network handled with success more than 5.3 million GPRS sessions, presenting an increase of 250% compared to the respective period last year. Overall traffic in the GPRS network during the sports events exceeded 290 million bytes, out of which 75 million bytes (or more than 25%) concerned volumes of data coming from visitors using the 71 foreign networks associated with Vodafone through relevant commercial agreements. During the event, Vodafone's network successfully carried off more than 35 million minutes of voice time.

Vodafone Spain, A. Menarini Diagnostics, Siemens Mobile and Pulso ediciones have announced the launch of the Medical Guard Diabetes(r) service. The Medical Guard Diabetes(r) service uses mobile communications to giver users control over their condition by sending the sugar levels to a database, completely automatically and safely. The patient's sugar level meter is connected to a mobile handset via a specially-designed electronic device (GMT). This service provides the user with his status and the exact time of the measurement, avoiding possible errors or forgetfulness.

Motorola and Partners Telemedicine, a service of Harvard Teaching Hospitals, have announced a collaboration to test MOTOHEALTH, a Motorola solution that uses mobile phones to help healthcare providers monitor chronically ill patients as they go about their normal daily routines. MOTOHEALTH uses FDA-approved body sensors to transmit data about the patient's condition to the healthcare provider via the patient's Motorola mobile phone.

The ITU Asia-Pacific Telecommunication Indicators 2004 report, issued at ITU TELECOM ASIA 2004, found that growth rates for fixed lines, mobile subscribers and Internet users over the last few years have soared in a number of countries across the region. Mobile subscriber numbers rocketed by 31% per year between 2000-2003 to reach 560 million — overtaking North America as the world's largest market. Numbers of fixed lines in the region also grew by 14% in the same period, surpassing the single digit growth rates seen in most other regions. The number of Internet users in the Asia-Pacific region also experienced rapid growth — 38% year on year from 2000-2003. At the end of that period, the number of Internet users in the region amounted to 255 million, surpassing North America, which grew by 18% to reach 227 million users by yearend 2003. In comparison, Europe/CIS grew by 20% from 2000-2003, reaching 191 million in 2003. New wireless technologies, which are currently being developed, could further help to extend the reach of ICTs into previously untapped rural or remote areas. At the end of 2003, total telephone penetration — fixed and mobile — in lower-income economies in the region was 22.6%, compared to 139.4% in the region's upper-income economies.

Nokia has launched a new barring solution for the safe and controlled usage of mobile content services as part of the Nokia Intelligent Content Delivery (ICD) solution. The barring solution is based on subscriber and mobile service recognition. It allows mobile users to control access to mobile content services - for example, parents can prevent children from accessing undesirable or unwanted services. The barring solution maps subscriber and service profile information to meet the growing demand for filtering out inappropriate mobile content.

Belgium's Proximus, the Government of Flanders and ITIS Holding are planning to pilot a new traffic collection technology for measuring real-time traffic flow based on anonymously sampling the positions of mobile phones in moving vehicles. The trial will be conducted in the Antwerp region.

Standards

Dennis Bodson, Senior Editor

IEEE-SA Standards Board approves P1616a

The IEEE SASB at their March 25, 2004 meeting approved P1616a, Standard for Motor Vehicle Event Data Recorders (MVEDRs) - Amendment 1: Brake and Electronic Control Unit (ECU) Electronic Fault Code Data Elements. The scope of this project is to develop an amendment for brake and transmission electronic control units that requires units to store a full history of electronic fault codes that are

time stamped using a recognized clock synchronized with other on-board motor vehicle event data recording devices. This project has particular emphasis on heavy vehicle Brake and Electronic Control Unit (ECU) fault code data elements. End users of this data include government, automotive industry, medical injury, legal profession, insurance industry, crash reconstructionists and academia researchers.

IEEE to Standardize Brake and Transmission Input to Motor Vehicle Event Recorders

The IEEE has begun work to ensure that brake and transmission data is recorded uniformly in motor vehicle event data recorders. The new project, IEEE P1616a™, "Standard for Motor Vehicle Event Data Recorders (MVEDRs), Amendment 1: Brake and Electronic Control Unit (ECU) Electronic Fault Code Data Elements," will require units to store a history of time-stamped fault codes synchronized with other on-board MVEDR devices.

The project responds to a safety recommendation made to the IEEE by the National Transportation Safety Board asking that data from brake and electronic control units for cars, trucks and other vehicles be included in the soon-to-be-completed IEEE P1616 MVEDR base standard. "This will be the first independent communications protocol for brake and transmission fault codes in highway vehicles," says Tom Kowalick, Chair, IEEE P1616 Working Group and Professor at Sandhills Community College in Pinehurst, N.C. "Our overall goal is to give all parties, from auto, truck, bus and other vehicle manufacturers to insurers, fleet owners, transit agencies and emergency first responders, ready access to uniform data."

"We will, in all likelihood, enhance IEEE P1616a so it becomes a broad standard that involves other technologies and end-user requirements beyond brakes and transmissions. We are thus seeking a wide spectrum of volunteers to work on IEEE P1616a. Everyone is welcome to contribute. Upon its completion, this amendment will be incorporated into the base MVEDR global standard."

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CDMA2000 1xEV-DO Revision

The CDMA Development Group (CDG)(www.cdg.org) reported that CDMA2000® 1xEV-DO Revision A has been approved by the 3GPP2 Technical Specification Group (TSG-C). Revision A is optimized for packet data service, and supports peak data rates of 3.1 Mbps on the forward link and up to 1.8 Mbps on the reverse link. The high data rates on the reverse link and low data latency will enable operators to deliver rich multimedia services, such as video telephony, and will enhance user experience.

"CDMA2000 technology continues to evolve to provide unparalleled speed and efficiency," said Perry LaForge, executive director of the CDG. "With CDMA2000 1xEV-DO Revision A, carriers will be able to further differentiate their services through a broad range of new, innovative wireless data offerings. Today's announcement is yet another milestone for CDMA2000 and we are extremely pleased with the progress 3GPP2 and the CDMA industry is making in delivering advanced technologies to meet the evolving needs of wireless communications."

CDMA2000 1xEV-DO Release A is an enhanced version of CDMA2000 1xEV-DO Release 0, which delivers up to 2.4 Mbps data speeds and has been commercially deployed since 2002. There are nine CDMA2000 1xEV-DO commercial networks in Asia, North America and Latin America today, with four more scheduled to be deployed in 2004. CDMA2000 1xEV-DO already delivers the highest data rates in commercial networks (average data rates of 300-600 kbps) and supports advanced data applications such as MP3 transfers and video conferencing, TV broadcasts, video and audio downloads.

Demand for advanced CDMA2000 1xEV-DO services is growing rapidly; the number of users reached 4.38 million at the end of 2003. In Korea, SK Telecom's CDMA2000 1xEV-DO base represents 25 percent of its CDMA2000 users after less than two years of service. In January, Verizon Wireless announced the nationwide expansion of its CDMA2000 1xEV-DO network after the successful introduction of its CDMA2000 1xEV-DO services in the San Diego and Washington, D.C. metropolitan areas in October last year.

IEEE-SA Standards Board Approves P1512.4

The IEEE-SA Standards Board on 24 June 2004 approved P1512.4, "**Standard for Common Traffic Incident Management Message Sets for Use in Entities External to Centers**," until 31 December 2008. A copy of the file can be found at http://standards.ieee.org/board/nes/projects/1512-4.pdf.

The scope of the standard addresses Traffic Incident Management Message Sets which will be exchanged by and between mobile data terminals in response vehicles including mobile command posts and to their respective response and/or dispatch centers such that the exchange of information will be standard and produce the needed response(s). This standard will be limited to common message sets for use by emergency management including transportation, fire/rescue, enforcement, HazMat, etc.

The purpose of proposed project is to produce a set of common message sets required for Traffic Incident Management exchanged between traffic incident responders. This standard will also address Traffic Incident Management Message sets that are exchanged between responders and other field assets in response vehicles, to centers, such that the exchange of information will be standard and produce the needed response(s).

IEEE Standard Amended to Enhance Wireless Local Area Network Security

With the security of information and access an ongoing concern in the use of wireless local area networks (WLAN), the IEEE has approved a new amendment that greatly enhances security in IEEE 802.11™ WLANs. The amendment, IEEE 802.11i™, will enable WLAN vendors to offer highly secure wireless network interface cards, access points and other products.

"IEEE 802.11i was developed by leading experts in network security to give end users and network administrators a high level of assurance that the integrity of their networks and data will not be compromised," said Stuart J. Kerry, Chair of the IEEE 802.11 standards committee.

IEEE 802.11i, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Medium Access Control (MAC) Security Enhancement," leverages security technology that has emerged since the original IEEE 802.11 standard was written in the late 1990s. These developments include the Advanced Encryption Standard (AES) and the IEEE 802.1X™ standard for access control.

"We wrote this amendment to support the wide range of users whose systems extend from small and simple units to large, complex networks," said David Halasz, Chair of the IEEE 802.11i Task Group.

The amendment allows for security improvements in existing wireless LAN products (through firmware upgrades). Most current products can be upgraded to use certain IEEE 802.11i features, such as Temporal Key Integrity Protocol and IEEE 802.1x authentication. This provides a considerable security improvement over the Wired Equivalent Privacy feature in the original standard. The amendment also contains options for backward compatibility with the original standard.

Even greater security can be gained in new products having new hardware architecture. Products coming on the market will be able to use the most advanced features of IEEE 802.11i, such as AES methods, key caching and pre-authentication for persistent authentication, which allows mobile stations to switch from one access point to another without incurring the time overhead of a key exchange each time.

"These and other enhancements in the amendment should assure that IEEE 802.11i-based wireless LAN products can meet the demanding security goals of the growing range of IEEE 802.11 WLAN applications expected in the future," Kerry said.

IEEE Approves Two Wireless LAN Projects for Fast Roaming and Mesh Standards

The IEEE has approved the start of work on two projects for fast roaming and mesh applications in wireless local area networks (WLAN). The fast roaming project, IEEE P802.11r™, will make it easier to use wireless voice-over-IP (VOIP) and other real-time interactive applications. The mesh project, IEEE P802.11s™, will extend WLAN range by allowing data to pass through wireless nodes.

The Fast Roaming Task Group will standardize MAC layer enhancements that minimize non-connectivity time between a roaming WLAN unit and the wired access points within a local area network. The standard will seek to foster the use of mobile, wireless VOIP phones and other time-sensitive WLAN applications by eliminating perceptible disconnections as 802.11™-based handsets transition from one access point to another during a handoff within an administrative domain of a local area network such as in a hospital, an office environment, or a college campus.

Task Group s will create a mesh service standard so wireless access nodes spread over a large area can connect to a main node. This arrangement will extend coverage beyond the typical WLAN connectivity limit of 300 ft. from an access point and make it quicker and easier to install WLAN service without hard-wired connections. In a mesh, a single access point can serve a large facility or broad sensor array. Mesh networks can also allow the military to place repeater nodes on mobile units that link to a central point or let a fireman become a node in a communications network in an emergency.

"The IEEE 802.11 Working Group is committed to creating standards for all aspects of wireless LAN operation worldwide," said Stuart J. Kerry, Chairman of the IEEE P802.11 standards committee. "Task Groups r and s reflect this commitment. The standards they will develop should help open a variety of new WLAN applications and continue to promote the rapid growth of IEEE 802.11-based wireless systems."

New IEEE 802.11 study groups are also being formed for wireless interworking with external networks and wireless network management. These will join the newly created Wireless Performance Prediction Study Group.

"I am pleased to see the continued strong industry support for the development of new projects within the Local and Metropolitan Area Networks Standards Committee (LMSC). This new work is an excellent indicator of the vitality of the data communications industry and the important role the IEEE 802 LMSC plays in it," said Paul Nikolich, Chairman of the IEEE P802 LMSC.

IEEE Publishes Guide to its Traffic Incident Communication Standards

Now that many states and localities have begun to implement the IEEE 1512® family of transportation emergency communication standards, the IEEE has issued a guide for decision makers and managers at public safety centers and transportation centers that

reviews the four standards in the series and how to put them into effect.

IEEE 1512 standards foster efficient communication in traffic incidents. They create common message sets so all parties involved, from a 911 system to the police to a public works department, can share information more easily in managing traffic incidents. The goal is to control resources so as to reduce congestion, secondary collisions, and the time it takes to clear an incident, as well as to improve inter-agency coordination and safety for travelers and emergency personnel.

The "Guide to the IEEE 1512® Family of Standards" covers such topics as the need for the standards, issues related to information sharing, table top exercises, and how to incorporate the standards into existing communication systems. It also includes implementation guidelines and case studies on the equipment, software and policy changes agencies have made to enhance interaction among 1512 standard users.

IEEE 1512 standards include a base standard and four companion volumes:

- The base standard, IEEE 1512™-2000, addresses message sets for traffic management, public safety and hazardous materials incident response in general.
- IEEE 1512.1™-2003 provides traffic management message sets for transportation and public safety agencies in transportation incident management.
- IEEE P1512.2™ provides message sets for interagency coordination, dispatching and asset management for transportation and public safety agencies.
- IEEE 1512.3™-2002 provides message sets for the management of hazardous materials in transportation incidents.

The "Guide to the IEEE 1512 Family of Standards" is publicly available at: http://grouper.ieee.org/groups/scc32/imwg/guide.pdf. To obtain copies of the IEEE 1512 standards, got to: http://shop.ieee.org/store.

IEEE 1512 standards are sponsored by the IEEE Vehicular Technology Society.

References

1. IEEE Press Release, May 9, 2004
2. IEEE Press Release, July 29, 2004
3. Press Release, Costa Mesa, CA, April 12, 2004
4. IEEE Press Release, July 22, 2004
5. IEEE Press Release, July 6, 2004

Changes to the Bylaws

The Board of Governors have approved the following changes to the By-laws. They consist mainly of minor clarifications of the text, but the main substantive changes are:

- Honorary membership can now be conferred on anyone, rather than only on existing VTS members.
- Ballots not longer explicitly have to be mailed, but can use whatever procedure IEEE recommend. In the future this could allow for electronic voting, for example.
- The Propagation Committee becomes a standing committee.
- The Electric Vehicles Committee is renamed the Vehicle Power and Propulsion Committee.
- The Meetings Committee is renamed the Conference Committee
- The Publications Committee takes on responsibility for the web site.

The detailed changes are below, with additions and ~~deletions~~ as marked.

II Membership

Section 2.0.

~~Honorary Membership in the Society may be awarded to a member by the Board of Governors.~~

The Board of Governors may award honorary Membership in the Society to an individual.

Section 2.1. Election

Nomination for Honorary Member may be made by the Society Awards Committee or by a petition signed by at least 50 members of the Society. An affirmative vote of at least two-thirds of the elected members of the Board of Governors ~~will be~~ is required to elect an Honorary Member.

Section 2.2. Eligibility

Honorary Membership may be granted an outstanding member who meets all of the following minimum requirements:

(a) He/She shall have made significant technical contributions to the field of interest of the Society.
(b) He/She shall have performed outstanding service to the profession and to the IEEE.
(c) He/She shall have been a member of the Society for at least 5 years.

V Nominations and Elections

Section 3.0. The Nominating Committee shall submit its slate of nominees to the Board of Governors in time to complete the election prior to the final Board meeting for the year. Upon acceptance by the Board of Governors, the Secretary shall forward the approved slate of nominees to IEEE Headquarters for submission to be mailed to the membership in accordance with using standard IEEE balloting procedures.

Section 4.0. The newly elected Governors shall be invited to attend the final meeting of the year of the Board but will not have the power to vote until their terms commence.

Section 6.0. The election of the officers of the Board of Governors for the following calendar year shall take place at the final meeting of the year of the Board of Governors. The election shall be the last order of business prior to adjournment. The Board of Governors shall elect a President, an Executive Vice President, a Vice President Mobile Radio, a Vice President Motor Vehicles, a Vice President Land Transportation, and a Treasurer. If there are more than 2 candidates for an office and no one receives a majority of the votes cast, a runoff shall be held between the 2 receiving the greatest number of votes. The Secretary shall be appointed by and serves at the pleasure of the incoming President. The Secretary need not be an elected member of the Board ~~He/She does not have to be a Governor~~, but must be a member of the Society. The first duty of the Secretary shall be to notify the IEEE Technical Activities Secretariat of the names of the elected officers.

VII Committees and Liaison Representatives

Section 1.0. Committees are established to facilitate the carrying out of the responsibilities of the Society in a particular area of endeavor. In some cases the responsibility is effected by a Liaison Representative(s) to an other entity. Committees are of two types: Standing and Ad Hoc. Standing Committees cover areas ~~which~~ that are permanent and continuous in nature. Ad Hoc Committees are set up for a specific purpose ~~which~~ that is temporary or non-continuous nature. Committees may, at the discretion of their Chairman or the Board of Governors, establish subcommittees. The committee chairman or liaison representative, unless otherwise specified by the Bylaws, shall be appointed by the Society President with approval by the Board of Governors. These individuals shall report on their activities to the Board on a regular basis.

VIII Standing Committees

Section 2.0. Technical Committees

At the beginning of the old clause Section 2.1, the text Section 2.1. A technical committee is deleted, and the remaining text added to clause Section 2.0, so it now reads:

Section 2.0. Technical Committees may be established by the Board of Governors to cover a special portion of the field of interest of the Society. This special Committee shall provide a source of technical and professional advice and assistance on the particular field of interest of the technical committee. In certain cases where a technical committee such as a technical standards committee is providing a service to or on behalf of IEEE as well as the Society, the coordination with the IEEE shall be effected to insure compliance with Institute requirements. If a technical committee covers a complete Field of Interest of the Society, e..g., Land Transportation, it may, at the discretion of the members concerned and approval by the Board of Governors, be designated as a Division of the Society, and function as a subentity of the Society.

Section 2.1~~2~~. Standards Committee

This Committee shall review the state-of-art and recommend the preparation of standards to the Board of Governors of the Vehicular Technology Society. Advance approval by the Institute Standards Committee shall be obtained prior to preparation. The standards may establish specific performance criteria, measurement techniques, definition of terms and practices and guides for specific applications. The substructure of the committee, shall be the responsibility of the chairman, subject to approval of the Board of Governors. The Institute Standards Committee may also request the Society Standards Committee to prepare standards in the field of vehicular technology.

Section 2.2~~3~~. Motor Vehicle Committee.
This committee shall cover those areas of vehicular electronics and electrical engineering ordinarily identified with the automotive industry.

Section 2.3~~4~~ Land Transportation Committee.
This committee shall cover the technology relating to electrical and/or electronic aspects of ground transportation.

Section 2.4~~5~~. Vehicular Power and Propulsion Committee ~~Electric Vehicle Committee~~. This committee shall cover the technology relating to the electrical and/or electronic aspects of electrically propelled road vehicles.

Section 2.5 Propagation Committee.
The scope of this committee encompasses radiowave propagation issues. The committee shall provide publications and services to the membership and to the Board as requested by the Board.

Section 3.0 Administrative Committees. Administrative Committees may be established by the Board of Governors to cover a particular area of Society operations. In certain cases where an Administrative Committee such as the Publications Committee or the Membership Committee is providing a service to or on behalf of IEEE as well as the Society, the coordination with the proper IEEE entity shall be effected to insure compliance with Institute requirements.

Section 3.1 Publications Committee The Publications Committee: (a) Recommends publication policy of the Society. (b) Implements the Publications Policy established by the Board of Governors. (c) Publishes a Society Transaction. (d) Publishes a Society Newsletter. (e) Assists in the publication of any special Society publications approved by the Board of Governors. (f) Recommends editors for the Society publication to the Board of Governors, (g) Recommends a Webmaster and maintains the Society's electronic publications including a website.

Section 3.2. Conference ~~Meetings~~ Committee. This Committee will e~~i~~nsure Society participation in the arrangement for Annual Conferences ~~Meetings~~ of the Society and in such other Conferences ~~meetings~~ of other organizations requested by the Board of Governors.

Section 3.7. Constitution and Bylaws Committee.
It shall be the function of the Constitution and Bylaws Committee to maintain an up-to-date record of this Constitution and Bylaws of this Society, and to ~~insure~~ ensure on a continuing basis that the Society's Constitution and Bylaws are in accord with IEEE requirements. It shall be the responsibility of this committee to advise the Board of Governors of any need or desire for change in the Society's Constitution and Bylaws and to

prepare such changes as are appropriate when directed to do so by the President or the Board of Governors. The chairman of this committee shall also serve as the Parliamentarian for the Board of Governors.

Section 3.9. Fellowship and Scholarship Committee

~~(c) The current awards are Dan Noble Fellowship (jointly with Motorola, Inc.), and the Transportation Electronics Fellowship.~~

Section 3.12. Executive Committee. This Committee advises the Society president in the performance of his/her duties. It cannot take any action ~~which~~ that will restrict the Board of Governors. The~~is~~ membership of this Committee shall consist of all the officers, the two most recent Past Presidents ~~the Past President, Senior Past President~~, and any other person the President may require. The President shall chair the committee.

IX Ad Hoc Committees

Section 1.0. Ad Hoc committees may be established by the President or the Board of Governors. If empowered by the President, the committee cannot continue beyond the term of office of the appointing President. If empowered by the Board of Governors, the life of the committee will be 1 year, unless otherwise ~~indicated~~ declared by the Board of Governors. The life of a committee may be extended by the Board.

Adopted and Approved March 6, 1953
Amended and Approved June 13, 1957
Amended and Approved April 20, 1959
Amended and Approved March 31, 1961
Amended and Approved October 15, 1969
Amended and Approved February 15, 1979
Amended and Approved January 23, 1993
Amended and Approved May 8, 2001
Amended and Approved May 18, 2004

2005 IEEE Vehicle Power and Propulsion (VPP) Conference

7-9 September 2005 Illinois Institute of Technology, Chicago, Illinois, USA

The 2005 IEEE Vehicle Power and Propulsion (VPP) Conference is co-located with the 2005 SAE (Society of Automotive Engineers) International Future Transportation Technology (FTT) Conference on the campus of Illinois Institute of Technology (IIT) in Chicago, Illinois, USA. Registrants for either conference will be able to attend the technical sessions of both. VPP conference will conduct sessions in different technical tracks and paper offers are being invited on the following or related topics.

- VPP Track 1: Vehicular Electric Power Systems and Loads
- VPP Track 2: Vehicular Power Electronics and Motor Drives
- VPP Track 3: Advanced Vehicles
- VPP Track 4: Energy Storage Components/Systems
- VPP Track 5: Modeling, Analysis, Dynamics, and Control

Papers should make a timely contribution to state-of-the-art technology, be of high technical and editorial quality, and be devoid of commercialism. Prospective authors of papers are asked to submit their paper proposals through the conference Web site by April 15, 2005. Each paper proposal must include: an abstract of 50-100 words and a digest of 3-5 pages (including figures and tables) stating the objective of the paper, outlining the problem requiring solution or the method of approach to research, being explicit with respect to the type of data to be included in the full paper, and summarizing the conclusions being made.

VPP/FTT General Chair: Prof. Ali Emadi
Illinois Institute of Technology, emadi@iit.edu
VPP Program Chair: Prof. John Shen
Uni. of Central Florida, johnshen@mail.ucf.edu
FTT Program Chair: Prof. Mehrdad Ehsani
Texas A&M Uni., ehsani@ee.tamu.edu

Conference of Interest

The following table shows VT-06 sponsored and co-sponsored conferences as well as related conferences not sponsored by the Society. While every attempt was made to ensure accuracy, you should contact the respective conference committee to confirm date and location.

DATE	CONFERENCE	LOCATION	WEB PAGE	
13-17 March 2005	WCNC 2005	New Orleans, LA	http://www.comsoc.org/confs/wcnc/2005/index.htm	
16-18 March 2005	2005 Joint Rail Conference	Pueblo, CO	http://www.asmeconferences.org/jrc05/	
11-15 April 2005	European Wireless 2005	Nicosia, Cyprus	http://www.vde.com/ew05	
16-20 May 2005	ICC 2005	Seoul, Korea	http://www.icc05.org	
29 May – 1 June 2005	VTC 2005-Spring	Stockholm, Sweden	http://www.vtc2005spring.org	
19-22 June 2005	IST Mobile & Wireless Summit	Dresden, Germany	http://www.mobilesummit2005.org	V
26-29 September 2005	VTC 2005-Fall	Dallas, TX	http://www.vtc2005fall.org	V
Q2 2006	VTC-2006 Spring	Melbourne, Australia	mailto:fzheng@ieee.org	

Conferences marked 'V' have open calls for papers as of 1 December 2004. This list is based upon the conference calendar at our web site, which is updated more frequently than this list can be. To access it go to the following URL: http://www.vtsociety.org/, then click on "Conference List" in the left frame. Corrections and additions to this list are most welcome, and should be sent to Tom Rubinstein at t.rubinstein@ieee.org.

Conferences marked '√' have open calls for papers as of 1 Decemeber 2004. This list is based upon the conference calendar at our web site, which is updated more frequently than this list can be. To access it go to the following URL: http://www.vtsociety.org/, then click on "Conference List" in the left frame. Corrections and additions to this list are most welcome, and should be sent to Tom Rubinstein at t.rubinstein@ieee.org.