IEEE Standards Education e-Magazine

The IEEE Standards Education e-Magazine: A publication for those who learn, teach, use, deploy, develop and enjoy Standards! Sponsored by the Standards Education Committee IEEE is committed to: promoting the importance of standards in meeting technical, economic, environmental, and societal challenges; disseminating learning materials on the application of standards in the design and development aspects of educational programs; actively promoting the integration of standards into academic programs; providing short courses about standards needed in the design and development phases of professional practice. Serving the community of students, educators, practitioners, developers and standards users, we are building a community of standards education for the benefit of humanity. Join us as we explore the three fundamental dynamics of standards--technology, economics and politics, and enjoy our feature articles about the use, deployment, implementation and creation of technical standards.

The IEEE Standards Education e-Magazine

3rd Quarter 2013, Vol. 3, No. 3

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Letter from the Editor-in-Chief

Yatin Trivedi

3rd Quarter 2013

Stand Up for OpenStand

Standards are ubiquitous in everyday life. From the daily use of weights and measurements to the safety requirements of a nuclear power plant, standards shape our lives beyond recognition. Technology standards have become an integral part of modern life, especially for those who use mobile gadgets, be it for improving their health, keeping track of their financial transactions or just staying in touch with the loved ones. Many of us use these standards with the sole expectation of seamless 'plug-n-play' so that 'everything just works.'

Having been involved in the development of many Electronic Design Automation (EDA) standards over two decades, I am usually curious about the history that precedes the usage of standards; that is, what caused the standard to be developed in the first place, who were the principal contributors, which organization was behind it, and, more importantly, how the standard was developed. This final question – the process by which the standard was developed – is an important one because it has global impact. For one thing, technology standards make their way into many different products and services that are universal in the way they are used. Even though there is need for localization, usually in form of local regulations, most technology standards are developed with no specific preference to nationality. These standards are often referred to as Market-Driven Standards. In that sense, there is a significant shift going on in the way technology standards are being developed. These days, the standards development organizations (SDOs) are global, open and inclusive in seeking participation. Their operating rules and regulations for technical committees are fair yet protective of the intellectual property rights (IPRs). They also maintain mutual respect for other SDOs and often collaborate to help build complex products and services such as Internet.

In this issue, IEEE-SA President Ms. Karen Bartleson writes about the OpenStand paradigm, a collection of principles in development of market-driven standards. A similar approach is explained by W3C's Mr. Daniel Dardialler. In another article, in her capacity as director of community marketing, Ms. Bartleson also shows how social media and standards affect you in everyday life. As many of our readers engage in developing and deploying standards, or teaching and learning standards, it is my sincere hope that you will practice OpenStand principles in your work.

In August, Standards Education Committee (SEC) sponsored a contest about engineering standards at UK&RI student congress. Papers from the top two winners are included in this issue. There is a lot to know about the impact of engineering standards. We have also included a paper by Ahmed Khan, Aminul Karim and Jennifer McClain, titled "The State of the Use of Standards in Engineering and Technology Education." It was recently presented at the 2013 Annual Conference of the American Society for Engineering Education (ASEE) and should be an interesting reading.

As always, SEC continues to encourage students and professors to engage in learning and teaching use of standards. Student Application Papers remain an integral part of our approach to enhance standards education. This issue includes a paper by three students from India who worked on a Wireless Energy Monitoring device using 6LoWPAN. It would be a good paper for you to review if you are considering submitting an application of your own.
The editorial board continues to search for topics for future issues. If you wish to submit an article, or would like to read about standards education, we would love to hear from you. Please write to us at: ezine-eb@listserv.ieee.org.

Yatin Trivedi
Editor-in-Chief

Yatin Trivedi, Editor-in-Chief, is Director of Standards and Interoperability Programs at Synopsys. He is a member of the IEEE Standards Association Standards Board (SASB), Standards Education Committee (SEC), Corporate Advisory Group (CAG), New Standards Committee (NesCom), Audit Committee (AudCom) and serves as vice-chair for Design Automation Standards Committee (DASC). For 2012, Yatin was appointed as the Standards Board representative to IEEE Education Activities Board (EAB). He represents Synopsys on the Board of Directors of the IEEE-ISTO and on the Board of Directors of Accellera. He represents Synopsys on several standards committees (working groups) and manages interoperability initiatives under the corporate strategic marketing group. He also works closely with the Synopsys University program.

In 1992, Yatin co-founded Seva Technologies as one of the early Design Services companies in Silicon Valley. He co-authored the first book on Verilog HDL in 1990 and was the Editor of IEEE Std 1364-1995™ and IEEE Std 1364-2001™. He also started, managed and taught courses in VLSI Design Engineering curriculum at UC Santa Cruz extension (1990-2001). Yatin started his career at AMD and also worked at Sun Microsystems. Yatin received his B.E. (Hons) EEE from BITS, Pilani and the M.S. Computer Engineering from Case Western Reserve University, Cleveland. He is a Senior Member of the IEEE.

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Welcome to the IEEE Standards Education e-Magazine

A publication for those who learn, teach, use, deploy, develop and enjoy Standards!

Technical standards are formal documents that establish uniform engineering or technical criteria, methods, processes and practices developed through an accredited consensus process.

Standards are:

- developed based on guiding principles of openness, balance, consensus, and due process;
- established in order to meet technical, safety, regulatory, societal and market needs;
- catalysts for technological innovation and global market competition.
- Knowledge of standards can help facilitate the transition from classroom to professional practice by aligning educational concepts with real-world applications.

IEEE is committed to:

- promoting the importance of standards in meeting technical, economic, environmental, and societal challenges;
- disseminating learning materials on the application of standards in the design and development aspects of educational programs;
- actively promoting the integration of standards into academic programs;
- providing short courses about standards needed in the design and development phases of professional practice.

Serving the community of students, educators, practitioners, developers and standards users, we are building a community of standards education for the benefit of humanity.
Join us as we explore the dynamic world of standards!

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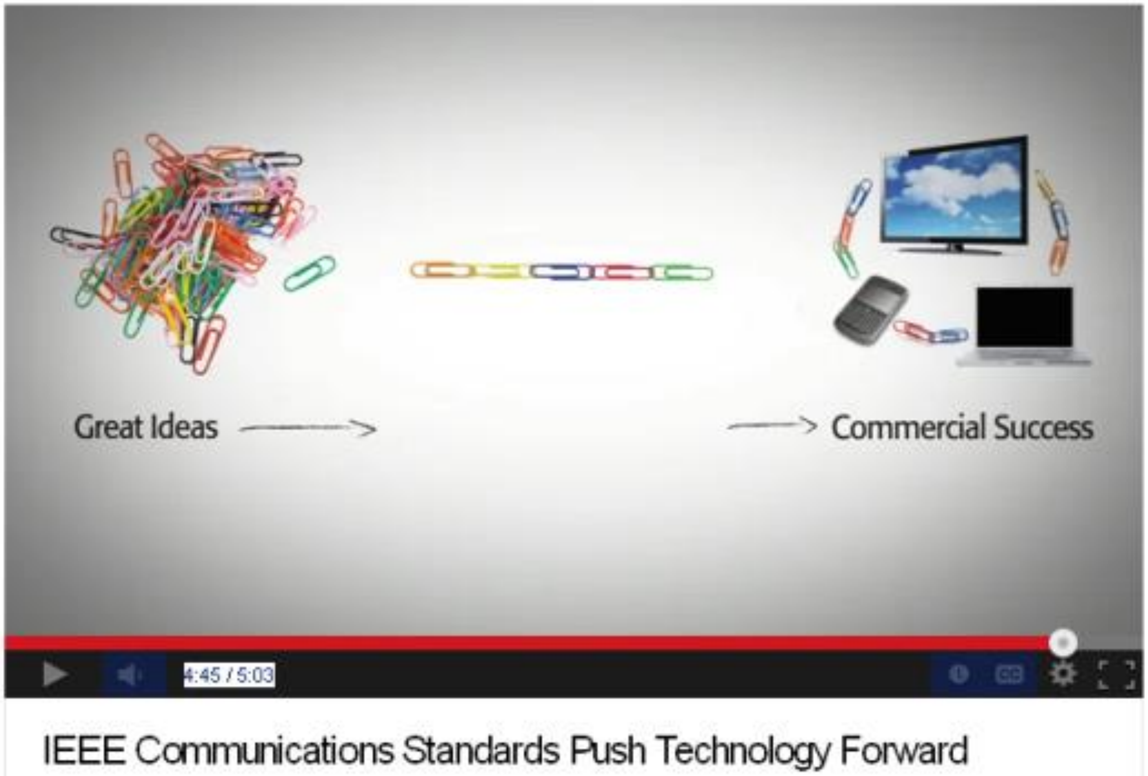
Video Series: Discussions about the Importance of Standards and Standards Education

IEEE Standards...Pushing Technology Forward

Learn the value of openly developed interoperable standards (5:04)



https://youtu.be/cVWjrtejS3A

Previous Videos

In part three of three, President of the IEEE Standards Association, Karen Bartleson talks with eZine Editor-in-Chief Yatin Trivedi about Global Collaboration and Standards Education (2:57).

Part one in three part series (2:48)
Part two in three part series (2:41)
Part three in the three part series (2:57)

IEEE Standards Association Past President Steve Mills and our Editor-in-Chief Yatin Trivedi discuss three fundamental dynamics of standards--technology, economics and politics, and address the importance of having a strong foundation in understanding standards and their impact on innovation.

Part three in the three-part series (5:44)
Part two in the three-part series (4:59)
Part one in the three-part series (5:53)

Videos will launch in You Tube.

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Feature Articles

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Market-driven Standards Fuel Technology Innovation

By Karen Bartleson, President, IEEE Standards Association

Third Quarter 2013

Two models co-exist for the way that technology standards are created, adopted and recognized around the world. - Both have served and will continue to serve humanity well. In broad strokes, nations come together through representative bodies to establish and recommend standards in the national body model. Then, there is a market-driven approach, in which developers and users of technology innovations drive development and adoption of global standards.
 OpenStand logo

It is this proven, market-driven standardization paradigm that IEEE and four other organizations sought to encapsulate in the "OpenStand" principles, which were announced in August 2012. The OpenStand paradigm (http://open-stand.org) demands:

- respectful cooperation among standards organizations;
- adherence to principles of standards development (due process, broad consensus, transparency, balance and openness in standards development);
- collective empowerment;
- availability of standards;
- voluntary adoption.

Collective Empowerment

The OpenStand principles, such as the commitment to collective empowerment, make me proud to work in the global standards community.OpenStand defines this point more precisely:

Commitment by affirming standards organizations and their participants to collective empowerment by striving for standards that:

- are chosen and defined based on technical merit, as judged by the contributed expertise of each participant;
- provide global interoperability, scalability, stability, and resiliency;
- enable global competition;
- serve as building blocks for further innovation; and
- contribute to the creation of global communities, benefiting humanity. [1]

In other words, standards organizations work to craft the best possible standards that balance technical considerations with other factors, toward the goal of innovation while enabling competition. Industry cooperates on standards and competes on products. And as clearly seen in a range of technology spaces, this approach works. Over decades, the principles captured in the OpenStand approach have proven their ability to advance technology innovation, foster global markets, and yield products and services that benefit humanity at more competitive prices.

A Rapidly Expanding Legacy of Success

The market-driven standards paradigm is not a new model at all. The principles encapsulated in OpenStand have been used effectively for decades in multiple technology spaces. OpenStand is based on the successful standardization model of the Internet, which can be considered nothing less than a worldwide economic and social marvel.

The reason the Internet behaves the same from market to market around the world is because of a suite of open, complementary, foundational standards that emerged from different global bodies. These include: standards for physical connectivity from IEEE, standards for end-to-end global Internet interoperability from the Internet Engineering Task Force (IETF) and standards for the World Wide Web from the World Wide Web Consortium (W3C), among other standards. The Internet's foundational standards were precipitated by collaborative processes drawing on the direct, open participation of innovators representing varied backgrounds, technical disciplines and geographic markets. Their impact has been revolutionary: the invention of a whole culture of border-crossing e-commerce, information sharing and community operations. Billions of people around the world have been touched by the Internet, and the technological innovations that have enabled the phenomenon have refused to be confined by any traditional industrial, technological or geopolitical boundaries. And those same standardization processes fuel the Internet's ongoing innovation today.

A suite of design automation standards that is widely relied upon by industry around the world is another example of the OpenStand principles in action. In fact, the global electronic design automation (EDA) industry has always used the market-driven standards model. The result is that SystemVerilog, the Unified Power Format (UPF),the Universal Verification Methodology (UVM), among many other standards support successful chip design flows and methodologies. They have helped enable tremendous innovations in the EDA industry's ability to define complex electronic solutions.

Other technology spaces in which the market-driven approach is prevalent include the global smart grid and "eHealth" medical-device communications efforts. OpenStand is designed to marshal grassroots inspiration, creativity and expertise across borders for any technology space in the contemporary, borderless world of commerce.

Conclusion

The market-driven paradigm defined by OpenStand fosters, at the same time, competition and sharing of lessons learned and R&D. In this way, the OpenStand processes lead to development of an open environment in which the gamut of established and emerging stakeholders globally are able to access each other's' work, ensure that their requirements are taken into account as technology standards evolve and discover new business models. Doors to new types of relationships and discussions are opened, and a borderless framework of standards development, participation and use emerges. Innovation and economic opportunity flourish, and humanity benefits.

[1] http://open-stand.org/principles/

Karen Bartleson
Karen Bartleson has over 30 years of experience in the semiconductor industry, specifically in electronic design automation (EDA). She is the 2013-2014 President of the IEEE Standards Association (IEEE-SA), whose mission is fostering technological innovation and excellence for the benefit of humanity. The IEEE-SA produces and maintains globally recognized standards, developed by more than 20,000 individuals worldwide. It offers over 1,100 active standards and sponsors over 500 active standards currently under development.

In 2012, the IEEE-SA, along with four organizations that provide standards that make the Internet work freely and openly, announced the "OpenStand" initiative for global, market-driven standards. Karen speaks on this and other standards-related topics at institutions and events around the world.

Karen is Senior Director of Community Marketing at Synopsys, Inc. Her primary responsibilities include initiatives and programs that increase customer satisfaction by developing communities - with social media and traditional channels - for standards, EDA interoperability, customer engagement, higher education, and research. She has served on numerous committees that create and govern technical standards.

One of the electronic design industry's first bloggers, Karen is the author of "The Standards Game" blog. She has published numerous articles on topics about standards and universities. Her book, "The Ten Commandments for Effective Standards", was published in May 2010 and is available through Amazon and other outlets.

Prior to joining Synopsys, Karen was CAD manager at UTMC (United Technologies Microelectronics Center), responsible for the design system used to create high-reliability application-specific integrated circuits. Before that, she worked at Texas Instruments as logic analysis manager where she was responsible for the development and support of TI's internal logic simulation products.

Karen was honored to be the recipient of the Marie R. Pistilli Women in Design Automation Achievement Award in 2003.

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W3C Self-Evaluation of OpenStand Principles

By Daniel Dardailler, W3C Associate Chair for Europe, Director of International Relations

Third Quarter 2013

Abstract

In August 2012, W3C co-signed the OpenStand principles. In this document we evaluate how W3C's current practices align with the principles.

Preamble

When **Tim Berners-Le**e invented the Web in 1989, he was already committed to principles of openness. The Web was created on top of the open Internet stack, so he already saw the value of such principles. This led to the creation of W3C with special elements to apply open principles to the Web. The Web being a global platform, Tim and other pioneers needed to involve everyone across a vast range of stakeholders, and so the organization had to be open to all. That led to the W3C process and key properties such as worldwide participation, due process, broad consensus, transparency, and technical merit.

The W3C Process and our practices for building consensus have evolved over time, including enhanced commitments to openness. An important step in 2005 was the adoption of the W3C Patent Policy, with its stated goal to assure that W3C Recommendations can be implemented on a Royalty-Free (RF) basis.

In 2012, we took another important step of codifying the shared principles of openness that underlie the processes of similar organizations in the Internet ecosystem: IEEE, IAB, IETF, ISOC, and W3C: **OpenStand.**

In the remainder of this document we examine how W3C practices map to the OpenStand principles.

Self-Evaluation

The first OpenStand principle is concerned with Cooperation between SDOs, and respect. Our public list of liaisons shows that we work with dozens of organizations ranging from fora to de-jure bodies. We are also transposing some of our most important specifications into ISO/IEC International Standards, through the PAS procedure, with a common goal of limiting fragmentation of global ICT standards on a national or regional basis.

OpenStand then lists five principles specific to standards development.

- **Due process** (equity and fairness, appeal, maintenance)

  The W3C Process embodies all these points, including consensus as a core value, a one-vote-per-related Members policy in rare cases when voting does occur, review and accountability requirements, and appeal processes (Formal Objections and Membership appeals). W3C has a process for modifying or updating standards.

- **Broad consensus** (all views are heard)

  Consensus is a core value at W3C. Our Groups have review responsibilities to address any substantive issue.

- **Transparency** (concerned with public notice for new work, clear participation rules, records of decisions, public comment periods)

  W3C publicly announces its activities to public-new-work@w3.org and new-work@ietf.org. All W3C drafts are public and comments from the public are welcome at any time. Most Working Groups conduct all their work on public mailing lists, which are archived indefinitely and publicly on the Web.

- **Balance** (no domination)

  As explained above, Consensus is a well-defined concept in our process. We avoid votes where we can. When a vote is necessary, each Member (or set of related members), regardless of its size, has one vote.

- **Openness**. (open to all interested and informed parties)

  Virtually all technical work within W3C happens on public mailing lists. W3C Membership is open to all, with a flexible fee structure. Employees of W3C Members may participate in any W3C Working Group, and many individuals not employed by a W3C Member participate under W3C's Invited Expert program. In 2011 W3C launched Community Groups (CGs) to increase participation in W3C activities. Anyone may propose a Community Group, and participation is free and open to all. As of July 2013, more than 3000 individuals are participating in 130 Community Groups.

  W3C technical reports are available publicly at no cost. W3C announces publication of all drafts on its home page and invites comments from anyone during the development of a standard and have accountability requirements for all review comments.

The next high-level principle in OpenStand is an affirmation of Collective empowerment with focus on:

- **Technical merit**

  W3C process includes wide review and resolution of dependencies with other groups, with a Candidate Recommendation phase which begins when W3C believes the technical report is stable and appropriate for implementation.

- **Global interoperability, scalability, stability, and resiliency**

  W3C also includes a Technical Architecture Group (TAG) whose charter to document and build consensus around principles of Web architecture.

- **Global competition**

  W3C's (Royalty-Free) Patent Policy seeks to lower barriers to entry into the market.

- **Innovation**

  Some of the principles articulated by the TAG in Architecture of the World Wide Web, Volume One include orthogonal specifications and extensibility, both of which speak to this principle. W3C Community Groups were created to foster pre-standards innovation.

- **Creation of global communities, benefiting humanity.**

  W3C has numerous standards related to accessibility, internationalization, security, and privacy, all indicative of our mission to make the Web available to all.

The fourth principle, Availability, is concerned with Intellectual Property (IPR) and implementation on fair terms. W3C's standards are publicly available at no cost, available for all times under our persistence policy, and developed under the W3C (Royalty-Free) Patent Policy

The last principle on Voluntary adoption is less relevant for W3C, since the Consortium has no enforcement power. Instead, we focus on creating an overall ecosystem supportive of global deployment. W3C engages with developers (through talks, conferences, documentation, and training), promotes interoperability (through test suites and tools), and maintains its Recommendations (by tracking errata and revising the Recommendations).

Conclusion

W3C's experience helped shape the OpenStand principles, and so it is not surprising for us to conclude we currently fulfill them. Our implementation is not static, however. The Web is transforming new industries and being transformed by them. Innovations and new capabilities are expanding the Web in unanticipated and exciting ways, and the standards landscape must adapt to remain relevant. The OpenStand principles continue to guide us as we increase our agility, openness, and usefulness to the market.

We hope that new generations of engineers joining the standardization train will be seduced by the framework W3C has put together in the past twenty years of its activities.

Daniel Dardailler is W3C (World Wide Web Consortium) Associate Chair for Europe, Director of International Relations. He joined the W3C team in Sophia-Antipolis, France, in July 1996. In 1997, he launched the Web Accessibility Initiative and was the Technical Director of the activity until 2003. As such, he participated in the design of some important standards like HTML, CSS, WAI Guidelines. From 2000 to 2005, Daniel was W3C Europe operational Director. In 2008-2010, he was active in the launch of the Web Foundation, a new organisation led by Tim Berners-Lee whose mission is to advance the Web to benefit humanity.

He's also served on the ICANN Board of Directors for one year, as W3C liaison and was also a member of the UN Internet Governance Forum advisory group from its creation to 2012. Daniel is a regular lecturer on academic topics related to the Internet and the Web at the University of Nice Sophia-Antipolis.

Prior to joining W3C, from 1990 to 1996, Daniel was working in Cambridge, USA, as a software designer and programmer for the X Window System Consortium and before that the OSF/TheOpenGroup. From 1986 to 1990, he was a Unix/Graphics engineer at the Bull Research Center in France.

Daniel holds a Ph.D. in Computer Science in Digital Typography and Networking from the University of Nice Sophia Antipolis (1989).

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Social Media, Standards & You

By Karen Bartleson and Sydney Burns

Third Quarter 2013

A critical part of maintaining a well-rounded education includes employing self-education techniques. Though there is an array of content circulating the web concerning engineering and standards, below you will find some hidden gems to add to your collection of self-education materials. By being involved in the current conversations on these sites, you can become an active member of the community. Social media today is viewed as a tool to connect young and experienced professionals to the world around them, and become more involved in their industry than ever before. Commenting on videos, articles, and forums is highly encouraged, although simply consuming content for yourself is beneficial too. Due to the wide spectrum of topics covered in these publications, there is always something valuable for everyone. Here are some excellent portals for self-education on standards and related topics:

1. **EE Journal** – This online publication is a news syndicate that focuses on electronic engineering trends, news, and analysis of current trends and topics for the industry. Their content channels cover a variety of topics including: design, and industries ranging from wireless to robotics. Find it here: http://www.eejournal.com/Simply search the site for "standards" and countless articles will come up to inform you of the standards being applied in a variety of technical fields. Like any search engine, the more specific you can be the better/more relevant information you will find.
2. **IEEE Standards Association Official Group on LinkedIn** – This is the official group on LinkedIn that covers news, trends, and industry discussions. Not only is it an excellent news source, but it can introduce you to the key people within the industry and the realm of IEEE standards. This group is a starting point to build your network and for furthering your standards education. Find it here: http://linkd.in/146IVUP.
3. **Conversation Central** – This is a videocast and podcast that also focuses on industry trends, with interesting live interview coverage of what is currently happening within the industry. You can view Conversation Central videos and subscribe to the podcasts on iTunes here: http://bit.ly/17ib13x. There are many topic categories, but the ones most relevant to you for standards education would be "standards" and "education". Of course, the other categories may appeal to you as well. Below are two intriguing videos from Conversation Central about standards, presented by industry leaders, for your viewing pleasure:

“Smart Grid, Smart Lives” – Within the videocast below Chris King, Chair of the Smart Energy Demand Coalition, talks about what Smart Grid is and what it means for energy savings, peak demand reduction, more renewable energy, cleaner energy, and convenience to consumers. The Smart Grid is a powerful example of what standards can do. Underlying the Smart Grid are existing standards, and new ones are being developed. For example, these standards support the communication system that connects sensors, controllers, meters, and other components of the grid. Smart Grid is a huge opportunity for standards to benefit humanity.

“Making the Internet Work” – The videocast below includes an interview with Russ Housley, Former Chair of the Internet Engineering Task Force. He explains the ins and outs of how the Internet works, what is currently trending, and what he sees for the future of the Internet. Russ talks about the process of making a standard in the IETF. Some of the standards that make the Internet work are HTTP, TCP/IP, and DNS. They are developed under a market-driven paradigm of open standards.

The Internet provides you many resources; however, finding the ones most relevant to your interests can be complicated at best. Once you have aggregated your top information sources, be sure to check in on a regular basis and interact with community frequently to stay connected and informed. Sometimes, the best knowledge can come from a news source you found yourself. And be sure to let us know how this eZine can serve you even better.

Karen Bartleson has over 30 years of experience in the semiconductor industry, specifically in electronic design automation (EDA). She is the 2013-2014 President of the IEEE Standards Association (IEEE-SA), whose mission is fostering technological innovation and excellence for the benefit of humanity. The IEEE-SA produces and maintains globally recognized standards, developed by more than 20,000 individuals worldwide. It offers over 1,100 active standards and sponsors over 500 active standards currently under development.

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Karen was honored to be the recipient of the Marie R. Pistilli Women in Design Automation Achievement Award in 2003.

Sydney Burns was the summer social media marketing intern at Synopsys. Her professional skills span public relations account management for tech companies worldwide, B2B marketing, and social media evangelism & management. She is currently studying advertising and creative strategy at the Academy of Art in San Francisco.

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The State of the Use of Standards in Engineering and Technology Education

By Ahmed S. Khan (DeVry University, Addison, IL), Aminul Karim (DeVry University, Downers Grove, IL) and Jennifer McClain (IEEE)

Abstract

During the past several decades, the economy of each nation has been significantly affected by globalization and technology. Government regulations and private sector standards affect a majority of world trade. Countries have been working together to establish international standards in almost every field. As a result, workers in all sectors need to have an understanding of standards. Engineering and technology students must not only possess an understanding of engineering standards and applicable government codes, but also learn to apply them in designing, developing, testing and servicing products, processes and systems. ABET's criteria for engineering and technology education require students to learn and apply standards in their class projects.

This paper is a follow-up of a 2006-2009 NSF initiative awarded to IEEE to help develop tutorials and case study modules for students and encourage standards education at college campuses. It presents the findings of a faculty/institution survey conducted through Electrical Engineering and ETD listservs representing the major engineering and technology disciplines during fall 2012. The intent of the survey was to the gauge the status of use of standards and regulations in engineering and technology coursework and to identify benchmark practices. In light of survey findings, recommendations are made to standards development organizations, industry and academia to help enhance the use of standards in engineering and technology curricula.

Introduction

Who are the national and international stakeholders of Standards?

In today's global economy, the importance of the formal study of standards has been highlighted by the new demands of international trade. A number of national and international organizations provide guidance for developing and implementing standards to ensure product safety, such as

- American National Standards Institute (ANSI)
- American Society of Mechanical Engineers (ASME)

- American Society for Testing and Materials (ASTM)
- Association of Electrical, Electronic and Information Technology,
- Germany (VDE)
- Canadian Standards Association (CSA)
- European Commission of the European Union (CE)
- Federal Communications Commission (FCC)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Transportation Safety Board (NTSB)
- Underwriters Laboratories (UL)
- US Food and Drug Administration (FDA)

At the national level, the ABET Criteria for Engineering programs also require students to incorporate engineering standards in their design experience1. The National Standards Strategy for the United States (NSS) demands increasing the endeavors to educate future leadership in engineering, business and public policy, on the role, value and importance of standards.2

At the international level, Prof. Shiro Kurihara has proposed a Three-Wave Model for the spread of international Standardization3. The first wave is driven by scientists, engineers, and technologists; during this phase standards for technologies, products, manufacturing processes, and services are defined. The second wave started approximately two decades ago because of the application of network and digital technologies in communications.

The main stakeholders in this phase are the corporate and business leaders who are interested in the development of standards and procedures for interoperable technologies to facilitate world trade. This phase takes approximately five years and is not suitable for products with shorter lifecycles. The third wave is driven by government and consumers and typically involves standards for services and for product maintenance to improve customer safety and satisfaction. This phase has necessitated the development of global standards and regulations in other areas, such as accounting, law, health, environment and safety. The three waves are interrelated, and input from each phase is fed back to the other phases leading to continuous improvement. In summary, the role of standards is: (i) significantly expanding since the creation of the Internet and the World Trade Organization (WTO), (ii) leading to an increased impact on business and society, and (iii) creating many more stakeholders.4

What are the standards skillsets that all graduates must know?

In 2003, a group of industry engineers and educators formed Standards in Education Task Force within IEEE to find the knowledge and skillset in standards that engineers and technologists must acquire before graduation. The process included faculty and student surveys to identify the current state of standards education. The task force made the following recommendation:[4]

1. Engineering and technology graduates should receive a comprehensive introduction on standards. This includes information on how standards are developed, how they impact the development of product, process, or service and how they benefit a country's economy.
2. Graduates should be familiar with key standards organizations in their disciplines and study standards or regulations in the context of an engineering case study.
3. Graduates should be able to identify and apply relevant standards in solving the expectations of an engineering design.

The IEEE task force also coordinated the development of educational materials to help engineering and technology programs incorporate standards education.

What are the fundamental dynamics of standards?

Harding (2011) observes that students need to develop an understanding of the interplay of three fundamental dynamics of standards: Technology, Economics, and Politics. In this regard students need to learn:

1. How standards play a part in their career;
2. How to think critically about standards development and technology solutions;
3. About the pace of standards development in terms of technical change;
4. How standards help drive innovation;
5. How standards development process provides good technical solutions;
6. Why standards are flexible.

What are the needs of undergraduate and graduate students?

Harding (2011) further notes that the state of standards education at the university level is diverse. There are different needs at the undergraduate and graduate levels:

1. Undergraduate students require a basic level of understanding that standards and standards organizations exist.
2. Students can use standards at the project level.
3. Graduate students use standards related to specific fields of interest.
4. Graduate students can explore the standards development process and the intersection with business interests.

What are practical factors that hinder the inclusion of standards in the curricula?

Some of the practical factors which hinder the inclusion of standards to the curricula are:[5]

1. Institutions are overwhelmed by the quantity of currently required materials;
2. Professors believe that they do not know enough about standards to teach the subject effectively or assess student work;
3. Required materials for teaching standards do not exist.

Harding (2011) observes that in addition to these, there is also a philosophical barrier, i.e., university education focuses on teaching the fundamental concepts and theories of engineering, and many professors believe that standards do not fit well in the foundation courses.

What is the state and status of Standards education in academia?

To gauge the state and status of standards education in academia, a faculty survey was conducted through Electrical Engineering and ETD listservs. The ETD listserv has a membership of more than 3800 faculty members. The following is a summary of results and recommendations based on faculty input and feedback.

Survey Results

Question 1: Do you teach standards and regulations in your curricula?

- Out of 149 respondents, 71% said yes and 29% replied no.

Question 2: Do students in your senior design course incorporate industrial standards and regulations in their senior design projects?

- Sixty-six percent of respondents said yes and thirty-four percent answered no.

Question 3: Which organizational resources are available for your students to access standards documents? (check all that apply)

- One hundred forty-nine respondents answered and 2 respondents choose not answer this question (see Figure 1).

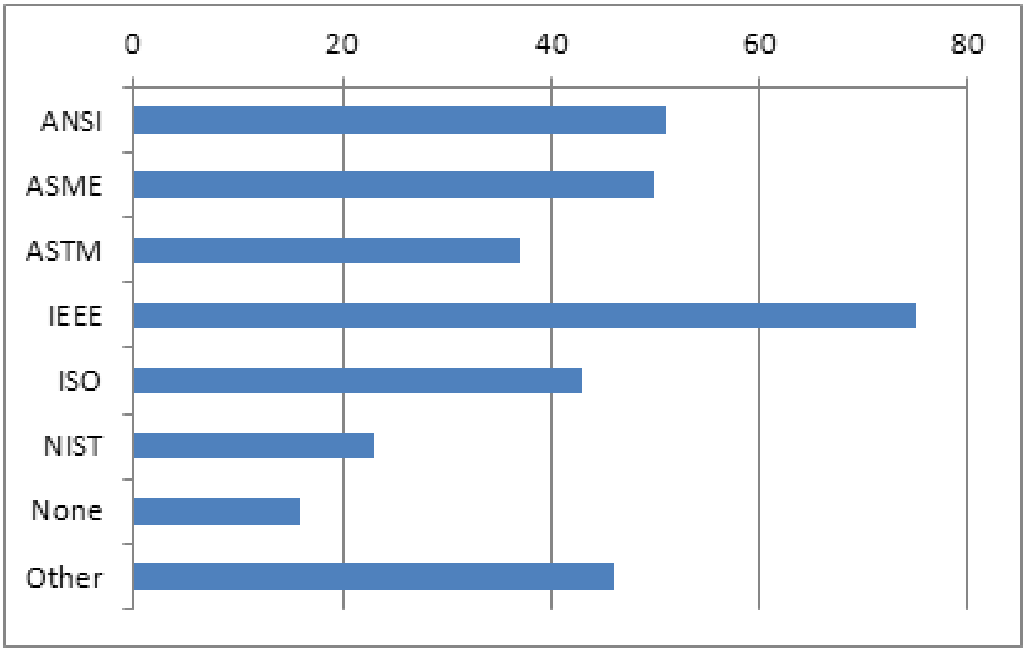

Figure 1: Types of Organizational resources available for students to access standards documents.

Question 4: What are the impediments to teaching and learning about technical standards? (check all that apply)

- One hundred forty-two respondents answered this question (see figure 2) and 9 respondents skipped this questions. The responses in terms of their percentages are listed below:
    - Lack of text books that provide the fundamentals and examples of application of technical standards (62%)
    - Cost of access to technical standards documents (56%)
    - Lack of faculty expertise on application of standards (49%)
    - Lack of access to technical standards documents (42%)
    - The “other” (21%) responses include: limited time, too many standards to teach, lack of faculty time, standards are continuously changing, standards use complex language, and lack of standards knowledge by faculty and administrators.

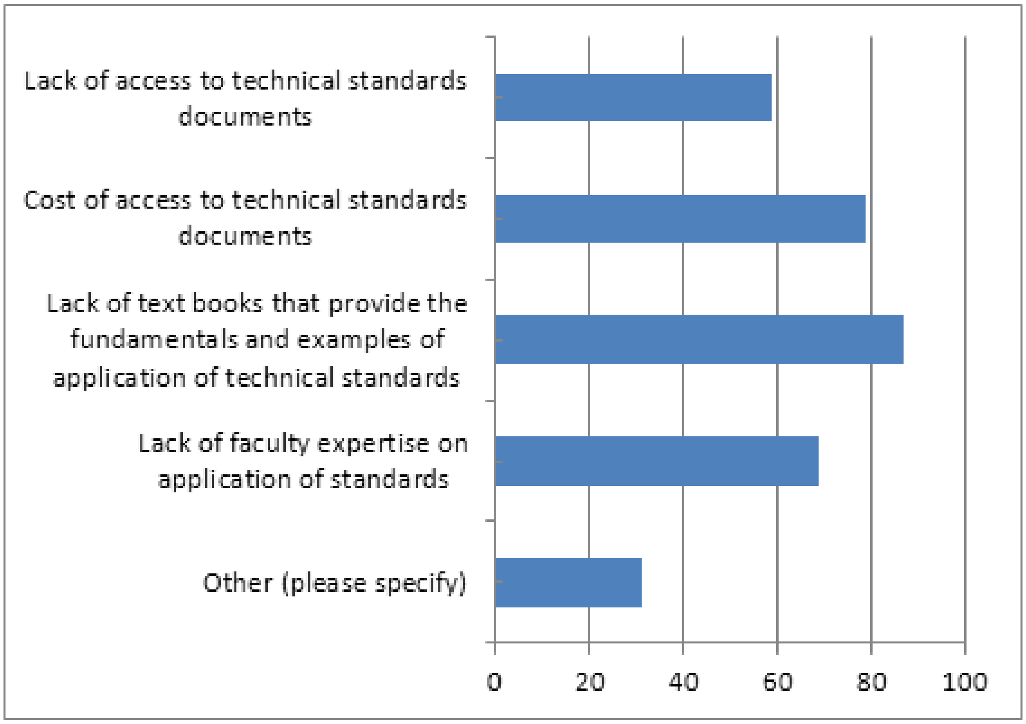

Figure 2: Response distribution of impediments to teaching and learning of standards.

Question 5: How can standard development organizations (SDOs) such as the IEEE, ASME, ASTM, and others help in mitigating the impediments to teaching and learning about standards?

- A summary of all responses is presented in Appendix A (of the paper presented at the ASEE 2013 Conference*).

Question 6: Which textbooks or reference books or resources are being used to teach standards in your curricula?

- A summary of all responses is presented in Appendix B (of the paper presented at the ASEE 2013 Conference*).

Question 7: Do you have any recommendations/suggestions for improving the teaching of standards and regulations in engineering and technology curricula?

- A summary of all responses is presented in Appendix C(of the paper presented at the ASEE 2013 Conference*).

Question 8: What is your department affiliation?

- One hundred fifty-one respondents answered this question. Figure 3 shows respondents' departmental affiliation. The other categories contain areas representing Civil engineering, Agricultural engineering, Manufacturing engineering, Construction engineering, Chemical engineering, Industrial engineering, and Aviation.

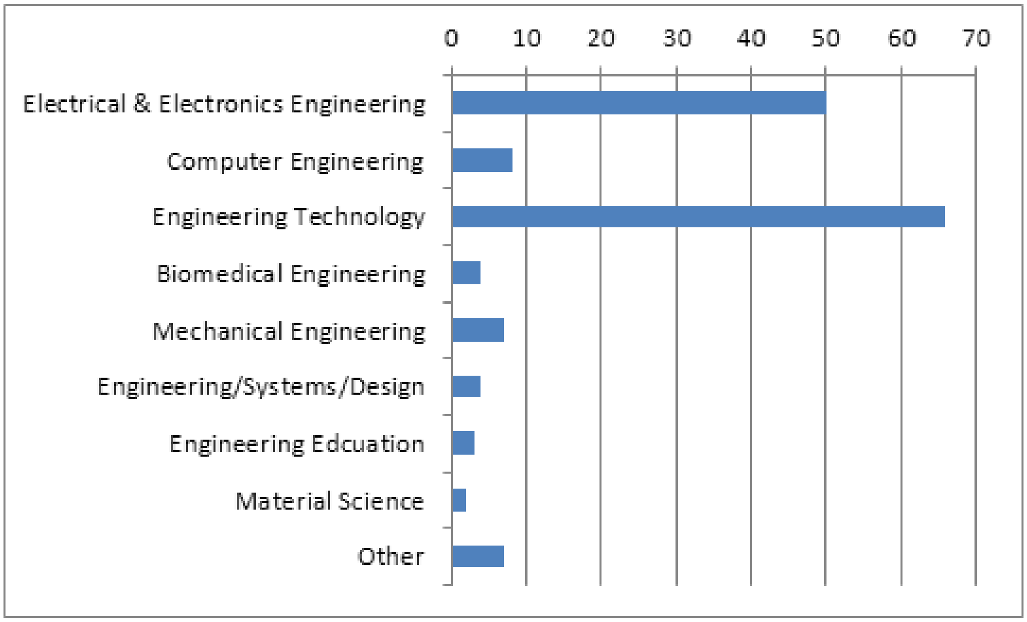

Figure 3: Departmental affiliation of respondents

Question 9. What is your email address (optional)?

- Sixty-one respondents provided their e-mail address, and 90 respondents choose to skip this question.

What are the Implications for Practice /Recommendation?

Based on the survey results and participants' feedback, the following recommendations are made for enhancing the teaching and learning of standards into the curricula and senior design projects.

The standards development organizations can help academia to better incorporate standards education in the curricula by:

1. Making standards available online to students and faculty at no cost.
2. Conducting standards education training programs for faculty.
3. Developing and disseminating standards education materials that can be incorporated into existing courses. Materials may include tutorials, case studies, webinar lectures by industry professionals on the basics of standards, and instruction on how to read and use a standard.
4. Developing and disseminating ancillary materials that provide guidance for faculty on incorporating standards education and evaluating output of student in standards education-related activities.
5. Sponsoring educational contests and events to encourage hands-on application of standards in student work.

Academia and industry should collaborate for:

1. Sponsoring authors to write/revise textbooks on standards and/or chapters on standards in textbooks for various engineering disciplines.
2. Developing examples of how to use standards in various foundation and senior design courses.
3. Conducting workshops and industry seminars on standards education for students and faculty.
4. Providing advisers to guide students on their senior projects based on standards.
5. Developing standards-based elective courses for undergraduate and graduate programs.
6. Providing internship opportunities for students in standards development organizations.

Conclusion

This paper highlighted the state and status of standards education in engineering and technology curricula by discussing the faculty survey conducted through Electrical Engineering and ETD listservs. It also made recommendations for improving the teaching and learning of standards in the engineering and technology programs vis a vis collaboration of academia and industry.

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* For a copy of the Appendices associated with this paper, contact Jennifer McClain, Program Manager, IEEE Standards Education, at j.mcclain@ieee.org.

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Jennifer A. McClain is the Program Manager for Standards Education in the IEEE Educational Activities Department. She has been with the IEEE for sixteen years. Ms. McClain spent eight years with the IEEE Standards Association aiding working groups with the standards development process, editing standards and as the Managing Editor of the Standards Information Network, publishing handbooks and guides to help with the implementation and understanding of standards. She holds a B.A. from Western Michigan University, Kalamazoo, MI.

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IEEE Standards Education Committee-United Kingdom & Republic of Ireland Student Branch Congress Paper Competition

By Yifei Wang, Student Activities Chair, IEEE UK & RI

Third Quarter 2013

About the Student Branch Congress

The IEEE United Kingdom & Republic of Ireland Section Student Congress 2013 (IEEE UK&RI SBC'13) is a student event modeled after the Region Student Branch Congress which is held every two years. The aim of this congress is to introduce students to the world of IEEE and to boost student activities in the section by training and motivating the student branch members.
The IEEE UK&RI SBC'13, held 6-8 September 2013, was approved by IEEE UK&RI section and hosted by the IEEE Student Branch at the University of Bath. The Congress received strong support from the IEEE UK&RI Section, the University (Dept. of Computer Science, Dept. of Electronic & Electrical Engineering, Faculty of Engineering and Design, Faculty of Science), Microsoft Research (Cambridge), Infonomics Society, IEEE UK&RI Communications Society Chapter, IEEE UK&RI Circuits and Systems Society Chapter and IEEE UK&RI Power and Energy Society Chapter.

Student Branch Paper Competition

This year, the IEEE Standards Education Committee (SEC), a Joint Standing Committee of the IEEE Standards Association Board of Governors and the IEEE Educational Activities Board, sponsored a UK&RI Student Paper Contest.

The SEC aims to promote that knowledge of standards helps facilitate the transition from classroom to workplace by aligning educational concepts with real - world applications and market constraints. In support of this the IEEE SEC sponsored the student paper contest on the subject:

What has been the impact of engineering standards on one of the following industry segments?

- Power and Energy
- Computers
- Communication
- Industry Automation
- Medical Industry

There were seven student paper submissions and each was carefully reviewed and evaluated by the SEC. Two winners were chosen. The first prize winner, receiving US $500 was Arinze Ekwosimba for the paper, "The Impact of Engineering Standards on the Communications Industry." The second prize winner, receiving US $300 was Abubakar Sani Hassan for the paper, "The Impact of Engineering Standards on the Power and Energy Industry." The IEEE Standards Education Committee congratulates the winners of the student paper competition, as well as all students who participated.

Yifei Wang, Abubakar Sasi Hassan, Arinze Ekwosimba

More highlights...

From 6-8 September 2013, over 80 students and IEEE officers attended from across the British Isles and European countries, with 14 IEEE student branches and 20 universities within the UK&RI section represented. The welcome speech was given by Deputy Vice-Chancellor, Professor Kevin Edge. Speakers from other countries in Region 8 such as Austria, Jordan, Portugal, Poland and Turkey were invited for the main sessions. The keynote speaker Adrian Stephens, Principal Engineer at Intel Corporation UK Ltd, gave a speech on “The Secret Life of an IEEE Standard.” The other keynote speech was given by Anthony Davies, Emeritus Professor of the Department of Electronic Engineering at King's College, University of London, on “A Career as a Reluctant Volunteer – from British Army to Undergraduate Student to IEEE Board of Directors.”

Yifei Wang received the B.Eng. degree in Computer Science from Beijing University of Chemical Technology, Beijing, China, in July 2009. After that, he continued his master study in the School of Astronautics at the Beihang University, Beijing, China, and he received the M.Eng. degree in Astronautics Engineering in March 2012. He is now working toward his Ph.D. degree in the Department of Computer Science at the University of Bath, UK, with fully financial support from the Overseas University Research Studentship. His research interests mainly include artificial intelligence, natural evolution, and bio-inspired computing theory and its applications. Mr. Wang was a winner for 2011 Richard E. Merwin Student Scholarship awarded by IEEE Computer Society in recognition of his exemplary involvement in student chapter activities as well as his excellent academic achievement. He was the former Chair of IEEE Student Branch at the Beihang University, and a former committee member of Geographic Unit Operations Committee (GUOC) China Section, IEEE Computer Society. He is now acting as the Student Activities Chair of IEEE UK&RI Section and a Student Ambassador of IEEE Computer Society.

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First Prize Winner....

IEEE Standards Education Committee-United Kingdom & Republic of Ireland Student Branch Congress Paper Competition

The Impact of Engineering Standards on the Communications Industry

By Arinze Ekwosimba, Graduate Student, Electronic Engineering, University of Southampton, United Kingdom

Third Quarter 2013

Abstract— The communications industry has experienced tremendous growth in recent years witnessing the rapid transition of transmission and networking technologies such that it is currently one of the world's most important industries. This growth has seen the expansion of the internet and mobile communication technology with much higher transmission capabilities than was previously possible and has brought about the emergence of many new market segments within the communications industry. The increased market size and complexity provides unique investment opportunities for vendors to harness the potentials of the industry but also provides the challenge of ensuring compatibility and interoperability between the products of different vendors. Engineering standards drive invention and innovation by enabling multiple players within the sector to play by a common basic rule which frees them to focus on devising unique products that differ in functionality, cost and features. This paper explores the impact engineering standards have on players within the industry and how it enables vendors maximize the potentials available within this industry.

Keywords—standards; communication; network; innovation; impact

I. INTRODUCTION

It is now a common feature for international travellers to effect payment abroad using credit or debit cards. In fact, cash withdrawal from ATM machines anywhere in the world is almost certainly possible using the debit/credit cards issued by one‟s local bank. Likewise, travellers can buy local SIM cards in any country visited with the certainty that they would work with their mobile phone and not have to worry whether the SIM card size would fit the SIM holder on the mobile phone. In a third example, a small business in Africa could order a printer from a European supplier with the certainty that locally sourced A4 papers would work with the printer. Furthermore, a consumer who buys a new TV set and HD box knows there would not be a problem with plugging both appliances to the mains and also with interconnecting both using appropriate cables; they surely should work; all things being equal.

The above examples illustrate how easy and convenient engineering standards have made life for the everyday consumer. Consumers do not have to worry about the low level details of how different appliances or tools inter-operate but rather on other factors such as functionality, feature variety and price. This in effect explains and graphically illustrates the huge impact of standards on a wide variety of industrial sectors in everyday life. This paper explores the impact of engineering standards specifically on the communications industry. In the background section, the evolution of standards is discussed; what they are, their use and how widely adopted they have become in a wide variety of industries. The next section explains the influence and relevance of engineering standards in the field of communications and why it has been very central to the growth of this industry. A number of scenarios showing the positive impact of standards are considered. The fourth section then looks into how innovation has been driven by standards within the industry with specific examples considered as well. The paper concludes with a critical analysis and evaluation of the various points discussed.

II. BACKGROUND

There are a variety of definitions for standards but [1] defines standards as “a set of characteristics or qualities that describes features of a product, process or service.” Standards provide a template against which requirements, specifications and performance of products can be measured. Without specific public or common standards, companies and other industry players would be left to devise their own private standards which their products and components adhere to. This would undoubtedly create a situation where equipment or appliances from different vendors are unable to inter-operate thus reducing the choice available to consumers while at the same time driving up prices as companies spend more on product development. In effect, the lack of standards creates pockets or islands of incompatible networks of mini standards. The attendant consequences of this include a reduced choice for consumers, higher cost and a possible stifling of growth and innovation.

Standards have been considered the life force of invention and innovation and have been crucial to the giant strides witnessed in the field of technology and engineering such that it is almost incomprehensible to imagine the world today without standards such as metric system, currency, electric lamps, railway tracks, bottle sizes, nuts and bolts. Standards have also been the driving force of business; or in the words of Acyl in [2], “standardization is above all an issue of business more than a technical issue.”

There are different types of standards available namely: voluntary consensus, de facto (ad hoc), consortia and regulatory (de jure) standards [1] and [4]. As the name implies, voluntary consensus standards are the product of concerted consultation, transparency and consensus building among relevant stakeholders. De facto standards usually are targeted at smaller market sectors than voluntary consensus standards and tend to be driven by commercial interest but have gained wide public or market acceptance. For example Ethernet, Pentium and PC BIOS are de facto standards. Consortia standards are driven by a select group of companies that have agreed to work together while regulatory standards are usually driven by government through its agencies and are enforceable by law [1].

The field of communications involves all forms of technology that facilitate the transfer of information from one location to another and has undoubtedly become one of the most important industries of the present age. This industry encompasses the means by which people and organisations communicate no matter their location such as the internet, mobile phone networks, LANS, WANS and satellites. Data communication and telecommunication (wireless and wire line) are both subsets of this industry with multiple stakeholders and players involved in their development and evolution over the years. The speedy growth of this industry tends to emasculate the progress made and the complexity involved in enabling the communication between varied devices and equipment. This is probably why it is easy to take for granted the fact that an O2 subscriber with a Blackberry phone can easily place a phone call to one on Virgin who uses an iPhone. This feat is only made possible by technical communication standards which ensure that all vendors – in this case, mobile phone makers and service providers – adhere to specific standards that ensure their products are compatible, adaptable and interoperable. Likewise in the area of networking, thanks to the efforts of the International Standards Organisation (ISO), there exists a standard for data communication within and between networks called the Open Systems Interconnection (OSI) reference model which codifies how data is transmitted over different kinds of networks [3].

III. THE IMPACT OF COMMUNICATIONS STANDARDS

Within the communications (and other) industries, private investors and companies are driven by the ultimate goal of maximizing profit from investments while the government always desires to uphold the common good and to provide a healthy and competitive investment climate as well. As would be expected, the consumer wants to have as many options or choices available together with low cost. It is therefore evident that these three parties have priorities that lie on different parts of the spectrum which presents the challenge of providing a solution that protects the interests of all stakeholders. Large corporations that can afford it could come up with their own proprietary standards governing the use of their products. Such companies would make big investments towards protecting their hold on a market segment and blocking out competitors if possible, for example, Microsoft Windows‟ hold on the operation systems market. The government in an attempt to create a level playing field and to ensure the common good could choose to create a public utility for a market segment, e.g. national telephone networks and national TV networks [6].

However, a multiplicity of proprietary standards within the communication industry would make it impossible for equipment from different vendors to interoperate; in other words there would be an uncompetitive market segmentation that could stifle growth and competition; moreover, interoperability is crucial to communication. On the other hand, public utilities create "unnatural" monopolies that stifle invention and innovation as there is no incentive for investors to come into a sector dominated by a public utility. This stifles growth as well and does not offer the consumer the benefit of improved technology. There is thus a dilemma of managing the desire for private gain versus the need to open up markets to competition and future technological breakthroughs [5].

Technical communication standards provide a template that guides the operation of stakeholders within the communication sector with respect to product development and marketing. These standards open up market segments to competition and innovation since vendors in abiding by such standards have to ensure compatibility and interoperability. Having standards also has the effect of increasing the cost of product development for companies since they have to adhere to standards for interfacing with other devices; in other words interoperability comes at a cost. However, this increased cost of production is balanced and in fact, outweighed by the access granted to a much larger market segment for the company's products. Furthermore, there is an improved and enhanced climate for competition and innovation since companies can focus more on product features and functionalities not codified in the standards. For the consumers, this presents the best of all worlds as they are presented with multiple options with the assurance that products from different vendors would be able to interoperate.

Different communications sectors are governed by standards maintained by standards organisations to ensure the common good, and maintain a balance between private and public interests as listed in Table 1. These organisations work to ensure that standards serve the important purpose and impact of technology penetration and market control.

Table 1: Table showing Standards Organisations within the Communications industry (reproduced from [4])

Standards Organisation	Standard
International Standards Organisation (ISO)	Open Systems Interconnect (OSI) reference model of networking
Institute of Electrical and Electronic Engineers (IEEE)	802.3 (Ethernet), 802.5 (Token Ring), 802.11 (Wireless LAN)
American National Standards Institute (ANSI)	ASCII and ANSI character codes, FDDI
International Telephone Union (ITU)	V series modems, error correcting and compression protocols, X series data communication protocols, H.323
Electrical Industry Association (EIA)	Cable specs especially 6 categories of UTP cable, RS232
Internet Engineering Task Force (IETF)	TCP/IP, SIP (a Voice Over IP protocol), All Internet protocols
World Wide Web Consortium (W3W)	HTML, XML, CSS, DOM

Another impact of engineering standards on the industry is that companies are forced to take standards seriously and do in fact get involved in standards development to ensure their competitive edge is protected. The participation of a variety of companies in standards development serves as a boost to the quality of standards and helps to speed up research and development in such fields or sectors.

IV. THE EFFECT OF COMMUNICATIONS STANDARDS ON INNOVATION

Civilization is powered by technology which in turn is a product of invention and innovation. If technology is to continue to promote the advancement of humanity, a conducive environment for innovation is paramount such that willing entrepreneurs would be encouraged to invest in areas in need of technological breakthroughs. The absence of innovation leads to stagnation and a reduction to simply periodic refinement or updating of existing technology. Over the course of human history and civilization, technology has been driven by a variety of standards.

Krechmer in [5] and [6] proposes three forms of standards that have evolved over the ages – units/reference, similarity, compatibility and adaptive standards. Units standards refers to the standardisation of weights and measures by different authorities to promote trade and commerce which later evolved into the currently used metric system. Similarity standards on the other hand specify the need for common properties between similar objects. For example, this would govern the size of car tyres and shirt sizes. Compatibility standards on their part define the communication interface between different entities. For example, a bold and nut can internetwork depending on the threading dimensions. The same would apply to a lamp socket and bulb. For data communication, this is defined by the OSI model which ensures different network devices can communicate. Adaptive standards provide a means to combine basic communication or internetworking of devices with adaptability features such that interoperation between interfacing ends of the access units of a device is possible [6] [8]. This leads to interoperability and the formation of open standards which are becoming more popular and widely accepted and even promoted by governments in some cases [9].

As earlier stated, there has traditionally been a conflict of interest between the private sector and the public sector with the former striving for maximum gain while the later desires the public or common good. A key impact of standards is that whereas standards strive for uniformity and openness, investors strive for uniqueness of products that would maximize profits. This conflict of interest is further illustrated in Table 2.

Table 2: Table showing uniqueness and uniformity trends (reproduced from [6])

Unique — Uniform

No externalities — Maximum externalities

one-of-a-kind products, initial ideas	stand alone manufactured products	products/services with private interfaces	public communications products and services, commodities

Standards creators — Standards seekers

Invention — Technology — Standardization

Investors strive to increase market share and hope that their products‟ popularity or acceptance could lead to a market-led (de facto) standard which would grant them an increased profit. This desire fuels the invention of new concepts that are eventually transformed and integrated through innovation into marketable products and services. If successful, and if the new products and services are widely accepted, this could lead to a new de facto standard which could eventually, through regulator efforts, become public standards for the benefit of the general public if necessary [6]. Another related benefit of standards is that due to the imposed uniformity requirement, smaller vendors can decide to concentrate on smaller components or market segments. This expands investment opportunities and also increases the options available to consumers. For example, thanks to the 30 years old Ethernet Standard, the Ethernet technology has witnessed tremendous growth and innovation that has led to its widespread adoption and has seen its speed grow from 2.94 megabits per second (Mb/s) to 100 gigabytes per second (Gb/s) [7].

Globally accepted standards do also provide investors with access to an increased global and international market making it easy, unambiguous and relatively seamless for vendors to enter different markets [10]. Another impact of standards on the communication industry is its effect on research and development, production, marketing and sales. This comes about because of the specifications inherent in standards for interfacing and basic operations [10]. Thus, when standards are readily available for a particular sector, it is easier and cost-effective for vendors to plan ahead on product development and deployment.

V. CONCLUSION

Engineering standards have had a positive impact on the direction of the communications industry; promoting competition, driving innovation and offering a wider selection for consumers to choose from. Companies like Microsoft, Apple, Samsung and Qualcomm are examples of companies that have benefited from the use of standards while also providing many other vendors the possibility of making products that are compatible with their products. This is made possible through defined interface or communication standards. With companies mainly after the maximisation of profits, standards help ensure their quest is not achieved at the expense of the common good. However, there have been cases where the conflict of interest between private interest and public good hindered or slowed the technological growth within a sector [6]. There have also been cases of patent wars between rival vendors struggling for the control of specific market segments. While engineering standards help provide a level field and easy entry into sectors for competitors, there still remains the challenge of finding a balance between private and public interests as discussed in this paper [3][11]. Nevertheless, engineering standards have enabled new frontiers to be reached in the communication industry through inventions and innovations with an overwhelming impact.

ACKNOWLEDGMENT

I am grateful to the IEEE University of Southampton Branch for the opportunity given me to be involved with the branch activities and to participate in the IEEE UK & RI Student Branch Congress 2013.

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Mr. Ekwosimba is in his final year of study for the Masters of Engineering, Electronic Engineering, at University of Southampton, United Kingdom. He has been a Student Member of the IEEE since 2010, and served as Secretary and then Chairman of the IEEE University of Southampton Student Branch. Currently he is still on the Student Branch Committee serving as External Liaison with companies. In the 2012/2013 academic year, he served as the Academic President for his department.

In the fields of Electronics and Computer Science (ECS), he completed 12 week internships with the Optoelectronics Research Centre (ORC), University of Southampton and Atmel Corporations, Whiteley, UK, in the last two summer holidays respectively.

Mr. Ekwosimba performs volunteer work for the International Office of the University of Southampton as a Student Ambassador, as a School and Parish visitor/campaigner for the Catholic Agency for Overseas Development (CAFOD) in the UK and for the Hospitalier Notre Dame de Lourdes, Lourdes, France. He speaks English, French and Ibo.

In his spare time, Mr. Ekwosimba enjoys music, reading, swimming, football and cooking. He finds the global reach, spread and relevance of the IEEE very good reasons to continue membership as it provides a unique opportunity to be at the forefront of the advancement of different facets of technology.

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Second Prize Winner...

IEEE Standards Education Committee-United Kingdom & Republic of Ireland Student Branch Congress Paper Competition

The Impact of Engineering Standards on the Power and Energy Industry

By Abubaker Sani Hassan, PhD Student, The Institute of Energy, Cardiff School of Engineering, Cardiff University, UK

Third Quarter 2013

Abstract— This paper reviews the impact of standards on the power and energy industry. Engineering Standards have played a vital role in ensuring the delivery of safe and reliable power supply with the conventional electric grid. However, with increase in Renewable Energy Sources (RES) and Distributed Energy Resources (DER) in the energy mix, there is the need to develop new standards and review existing ones to cope with the technical challenges of new technologies. This paves the way for an evolving smart grid with RES, DER and Electric Vehicle (EV) integration.

Index Terms—Power and Energy, Standards, IEEE Standards

I. INTRODUCTION

Standards are essential guidelines that are necessary in order to facilitate safe and efficient conduct of engineering processes and manufacturing [1]. According to [2], standards could be defined as a set of guidelines and technical specifications, a sort of "how to" instructions for users, designers and manufacturers. They promote safety, reliability, productivity, and efficiency in almost every industrial activity that relies on engineering components or equipment. Technical standards are formal documents that establish uniform engineering or technical criteria, methods, processes and practices developed through an accredited consensus process.

The power and energy sector is key aspect of an entire energy system and therefore requires the development of standards that ensures the safe deployment of technologies that will enhance the efficiency of operation of this key industry. A lot of standards have been developed by IEEE, IEC and CIGRE for the power and energy industry [3]. The IEEE is a global developer of standards built on a special platform with inputs from major stakeholders. Standards have played a vital role for legacy systems in power and energy and for emerging aspects of the power and energy sector like distributed generation, renewable energy integration and smart grids.

Engineering standards have played a key role in leveraging efficient deployment of new technologies within the power and energy industry.

This paper reviews some of the current engineering standards in the power and energy industry. The impacts of some of the current engineering standards are highlighted and the need to develop new for the emerging smart grids and EVs is discussed in section III. The existing standards need to be reviewed to facilitate interoperability with the new systems in the power and energy industry.

II. METHODOLOGY

A review of some the current engineering standards in the power and energy industry is carried out.

A. Standards in the Power Industry

According [4], there are more than 1300 engineering standards at various stages developed by the IEEE. These standards are necessary to ensure safety of operation of the power system especially with distributed generation and renewable energy integration likely to change the future energy mix. International standards are very important for design engineers and researchers in power quality [5]. This is essential in-order to implement technology management that will ensure safety and reliability in the power industry. IEEE standards in the power sector includes different aspects of the power system which includes but are not limited to [6].

These standards ensure safety of existing systems and interoperability between legacy systems. For example the IEEE 3001.8™ Standard lays out the importance of metering in yielding effective energy management systems and it also stipulates the constraints that must be met when deploying the latest metering technology. New standards are also emerging in the power industry to provide the necessary reference for innovation in the changing power system. These include:

- IEEE Smart Grid Research IEEE Grid Vision 2050
- IEEE 308-1971 IEEE Standard Criteria for Class IE Electric Systems for Nuclear Power Generating Stations
- IEEE C93.3-1995American National Standard--Requirements for Power-Line Carrier Line Traps
- IEEE 1816-2013IEEE Guide for Preparation Techniques of Extruded Dielectric, Shielded Cables Rated 2.5 kV through 46 kV and the Installation of Mating Accessories
- IEEE 1017-2013 IEEE Recommended Practice for Field Testing Electric Submersible Pump Cable.

B. Standards in the Energy sector

Energy conservation represents the different technologies employed in order to minimize energy consumption. Engineers working on this aspect should be versatile with a multidisciplinary approach like electrical applications, power quality, control techniques heat transfer and ability to understand industrial processes. Energy efficiency and conservation are increasingly playing a significant role in the mitigation of climate change and security of energy supply. According [7] the 1970s oil crises have been more effective in reducing energy demand and emission of CO2 than the energy efficiency and climate change policies of the 1990s. Example Denmark was able to improve significantly energy efficiency through renewable energy integration due to the 1970 oil crises.

Table 1 summarizes some of the impacts of energy efficiency measures in the International Energy Agency (IEA) member countries.

Table 1: Impacts and challenges of energy efficiency measures in IEA countries [7]

Sector	Impacts	Future work/Challenges
Building	• Full implementation of building certification in several EU countries • Policies promoting passive energy houses • Energy efficiency requirements in building codes	• Establish stronger energy efficiency requirements for buildings • Strengthen support for passive houses and zero-energy buildings • Increase promotion of energy efficiency windows and glazing.
Industry	• High coverage of industry energy statistics • Policies promoting energy management • Ad hoc policies for SMEs • Policies for cogeneration, energy efficient electric motors	• Establish measures to optimize energy efficiency in motor driven systems. • Set up policies and measures to assist SMEs
Transport	• Policies aimed at rolling resistance of tyres. • Fuel efficiency standards for light and heavy vehicles (JP only) • Eco drive policies • Terminating schemes encouraging the purchase of more efficient and less polluting new vehicles and of recent Electric Vehicles (EVs)	• Ensure implementation of fuel efficiency. Standards of planned policies. SAE IEEE EVs V2G • Create fuel-efficiency standards for heavy duty vehicles

Table 1 shows positive impacts in the IEA countries in covering the energy industry statistics as well as effective energy management systems. However, it can been seen that energy efficiency in motor driven systems need to be improved by developing new engineering standards to cover this aspect. Cogeneration is another positive aspect that has been influenced by energy efficiency standards especially with Combined Heat Power (CHP) deployment in countries like Denmark with high share of renewable energy sources in the energy mix. Some of the current standardization efforts in energy efficiency are summarized below [7].

1. International Standard Organization (ISO): The key areas identified by the ISO relating to energy efficiency and renewable energy sources (RES) include:

- Methods of calculations
- Standards in Energy management
- Biofuels
- Retrofitting and refurbishing
- Buildings

2. International Electro technical Commission (IEC): The IEC approach energy efficiency systematically and came up with the following subsidiaries:

- SG1 Energy Efficiency and RES
- SG3 Smart Grid
- SG4 Low Voltage Direct Current (LVDC) for distribution systems with up to 1500 VDC

3. CENELEC and CEN: They are standardization organizations that began in 2002 in order to clarify the general strategy in the energy efficiency sector.

III. IMPACT OF STANDARDS

Even with these policies and standards, difficulties are encountered in the implementation stages. Some of the key issues in a scenario low engineering standard implementation are [7]:

- Lack of awareness in the saving potentials of energy efficiency
- Inadequate information on performance efficiency of complete systems
- Split incentives

Standards can come to the rescue by providing common measurement and test methods to assess the use of energy and the potential reductions obtainable by adopting new technologies and processes. Providing codes of best practices and management processes for efficient energy use and conservation.

Engineering standards provide guides and design checklist which may be applied to both the design of new systems and the retrofit of existing systems. The impacts are summarized on the existing conventional power and energy industry. The likely impacts of engineering standards on emerging smart grids and electric vehicles are also discussed in A and B below.

A. Power and Energy sector

The development of standards in the power and energy industry is vital to the evolution of the power system to a smart grid with increased renewable integration penetration. There are many engineering standards that have been benefitting the power and energy sector by saving design time and cutting cost.

One of such standards is IEEE 519-1992 Recommended Practices and Requirements for Harmonic Control in Electric Power Systems. According [5], this standard deals with power quality issues at the following levels:

- Distribution Systems (120V-69 kV)
- Sub-transmission levels (69 kV-161 kV)

The IEEE 519-1992 defines the identification of power quality distortion as a change in the voltage waveform from a sine wave to another form and a shift in wave amplitude from the established reference level. As such with the aid of this engineering standard (IEEE 519-1992), power quality distortion could be monitored at generating plants, transmission system, transmission lines, major substations, distribution systems, distribution transformers, service equipment and wiring systems in buildings.

In the US, many states have adopted the Renewable Electricity Standards to ensure the safe and reliable increase of RES in electricity generation [8]. According [8], two-thirds of the wind power integration between 1998 and 2003 (3300MW) in the US occurred in states that deployed a RES standard program. With the increase in penetration of RES and other Distributed Energy Resources (DER) into the conventional power and energy sector, there is need to continuously update existing standards. Standards are continuously updated in order to meet up the requirements of new technologies (smart grids, electric vehicles, vehicle to grid etc.) in terms of interoperability, quality assurance, supply chain, design time, regulatory compliance, environment, health, and safety.

B. Smart Grids and EVs

The conventional power system relies on large power generating stations as shown on Figure 1. However, with distributed generation (DG), DER can be located throughout the distribution system [1]. With this arrangement, the one way power flow of the past gives way to reverse power flows. This introduces technical challenges and power quality issues and hence the need for standards to ensure quality and safety and regulatory compliance.

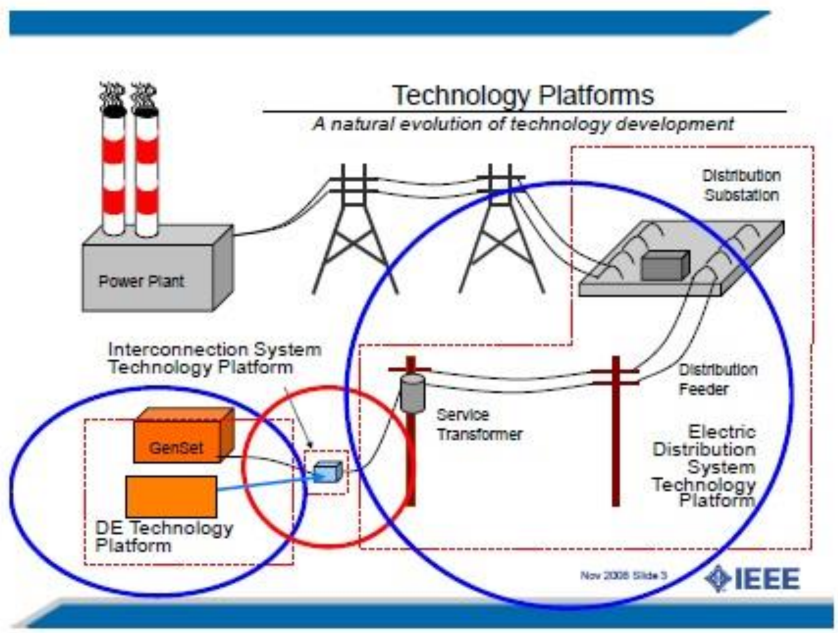

Figure 1: Existing grid [1]

The IEEE 1547.3 Guide for monitoring Information Exchange and Control Support is an example of existing standard that defines the connection of Distributed Generators (DGs). Distributed Resources (DR) covers electricity sources not connected directly to the main transmission system and near to the load being served with DGs and energy storage systems. DER within this standard means CHP/cogeneration with in-built load and energy management. Figure 2 highlights these interconnections.

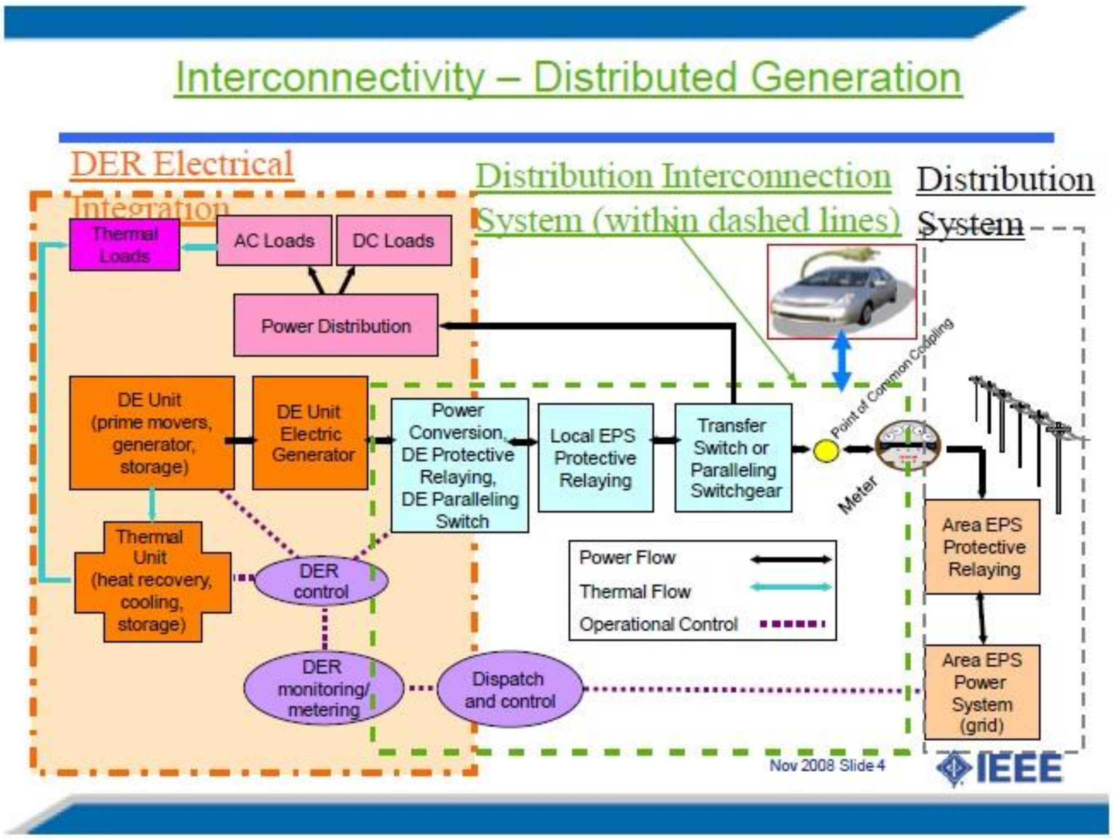

Figure 2: Network elements expansion at the distribution level [1]

The present conventional power system has grid monitoring capability for billing purposes only. A number of metering standard requirements for the smart grid are developed by Department of Energy and Climate Change (DECC) in the UK and the ANSI C12, IEEE SCC 31 Automatic Meter Reading and Related Services. With the integration of DER and penetration of RES into the grid however, standard development and revisions are required to cover the key areas like data management, communication (like broadband over power line) and control. Figure 3 shows the existing IEEE 1547 series of DG interconnection standards.

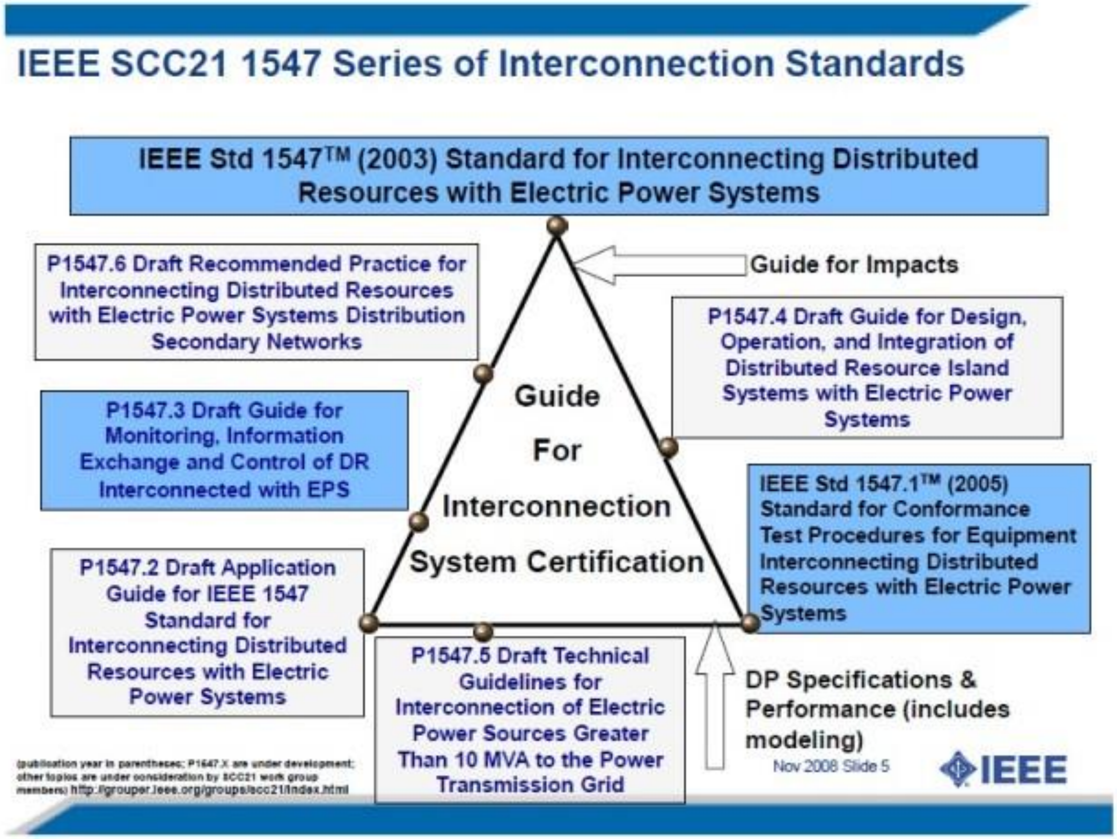

Figure 3: IEEE 1547 Series of Standards

It has been suggested in [1], that the IEEE 1547 standard series for DERs and DRs can be expanded to include electric vehicle (EV) connectivity to the grid with specific emphasis to the following aspects:

- EV guide for connection to the grid
- Functional requirements for EV connection to the grid
- Tests to validate the functional requirements.

Recently the Institution of Engineering and Technology (IET) published the Code of Practice for Electric Vehicle Charging Equipment Installation. It is a guidance on EV charging equipment installation, a key developing area which is not covered in detail by the current edition of the Wiring Regulations (BS 7671) or the IET's Guidance Notes [9].

The IEC and SAE have developed standards for EV charger rating that are widely in use for EV charging currently as shown in Table 2 [10].

Table 2: EV Standard charger ratings

Current (A)	Voltage (Vac)	Phase	Power (kW)	Standard
10	120	1	1.2	SAE J1772
10	230	1	2.3	IEC 62196-2
16	230	1	3.7	IEC
30	240	1	7.2	J1772
32	230	1	7.4	IEC
16	400	3	11	IEC
32	400	3	22	IEC
80	240	1	19.2	J1772
63	400(EU)	3	43.6	IEC
63	480(US)	3	52	IEC

The single phase (1.2 kW) domestic chargers are widely in use. As higher penetration of EVs increase fast chargers of 3 phase 50 kW are likely to increase.

The growth in EV penetration is anticipated to increase significantly from hybrids Plug-in Hybrid EVs (PHEVs) to Battery EVs (BEVs).

The penetration of EVs in the coming years will have an impact on the electricity demand, disposal and battery recycling [11]. Hence the need to for standards to address concerns like:

- Charging systems: Although American Society of Automotive Engineers (SAE) has developed standards like J1772, the standards need to be harmonized to ensure interoperability.
- V2G Reverse Power flow, is another major source of technical challenge as deep cycles will lead to significant battery degradation. In a study [12], the economic gains obtained by aggregators participating in balancing and ancillary services were shown to be attractive but with significant cost of battery degradation and power quality issues.
- Interoperability with adaptation to building and fire codes.
- Health and safety of using EV with V2G functionality.

Figure 4 shows the likely aspects for standard development in order to fully realize the potential of V2G as flexible storage system for the utility grid.

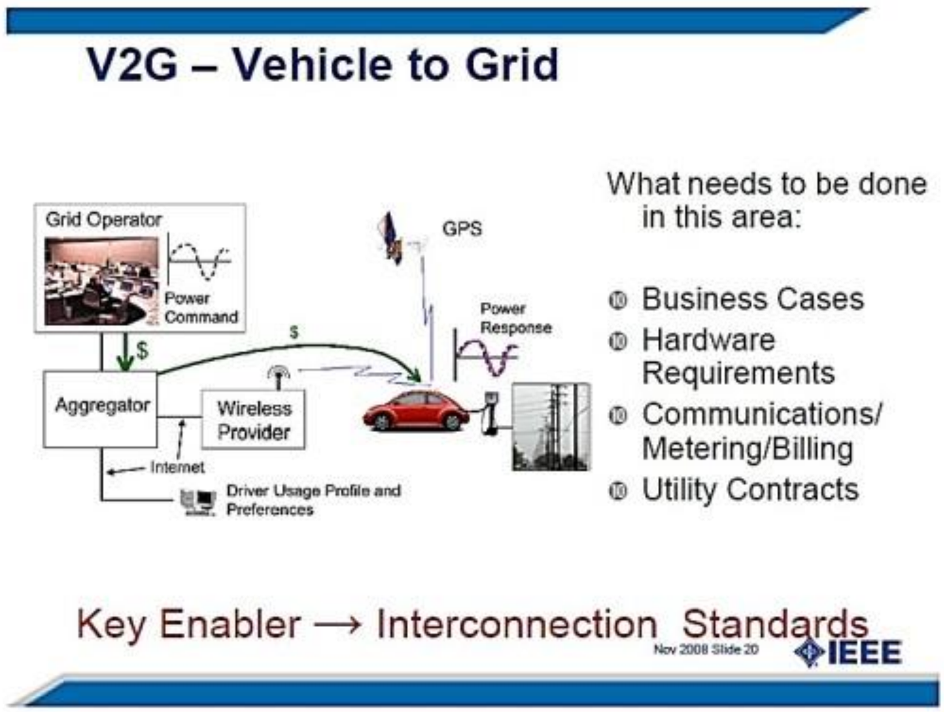

Figure 4: V2G key areas requiring new standards

Business models have to be developed to show the economic returns aggregators and EV owners will have in return for participating V2G balancing market. To achieve this, the technical barriers have to be identified and standards developed in V2G power electronic interfacing with the grid.

IV. CONCLUSION

The power industry has been evolving stably supported by thousands of standards developed by the IEEE, IEC and other Standard Development Organizations (SDOs). These standards have helped in ensuring interoperability, reliability, power quality, compliance with regulations and safety in the power and energy industry globally. However, with the increase in RES, and DER in the power and energy industry, the case for the smart grid is increasing the need to develop new and revise existing standards in order to accommodate intermittent RES and DER especially with EV penetration. Currently the IEEE 1547 series of interconnection standards only covers DG interconnection with the power system. With the anticipated high growth of EV deployment, the standards for EV with V2G functionality needs to be developed in order to achieve the potential of V2G balancing services for the grid.

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He wishes to acknowledge his PhD scholarship sponsors: Petroleum Technology Development Fund (PTDF), Nigeria.

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Introduction to Student Application Paper, "Wireless Energy Monitoring Solution Using 2.4 GHz 6LoWPAN"

By Dr. Dilip Kumar Kothari, Professor and Section Head, Electronics & Communications Engineering Programme, Electrical Engineering Department, Institute of Technology, Nirma University

Third Quarter 2013

The developing world, specifically India, faces a major energy crisis with a vast imbalance between supply and demand of electricity. The Energy Statistics 2013 (http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2013.pdf) report brought out by the Ministry of Statistics and Programme Implementation (MOSPI), estimates an overall energy deficit of 8.7% in India. It also cites a need for "conservation and efficient utilization of energy resources" that will play a pivotal role "in narrowing the gap between demand and supply of energy." Conversation of electricity has maximum potential for improvement at the consumer level, where wastage is most likely to occur. Automatic dimming of lights and turning off appliances when not in use, for example, can be a major cost-advantage for the consumer while enabling efficient distribution of load in the grid.

The paper, Wireless Energy Monitoring Solution Using 2.4 GHz 6LoPAN, discusses the design and implementation of a domestic energy monitoring device, rather node, which can be either integrated into a power outlet or into a device whose energy is to be monitored. These nodes, unlike smart meters are under the control of the consumer, leaving him to decide whether the energy company has access to his consumption data. The metered energy information is wirelessly sent to a central router which keeps track of energy consumption of every appliance connected to the wireless sensor network (WSN). This "edge" router also provides an interface to the consumer to keep track of his consumption patterns. The choice of standards for this application required a careful evaluation of its requirements: a highly scalable network of low-power, low-profile energy metering nodes. IPv6 over Low Power Wireless Personal Area Networks (6LoWPAN), in part, meets the scalability needs of the application, while IEEE 802.15.4 provides a low-power wireless Physical (PHY) and Media Access Control (MAC) layer for it. The authors have documented several challenges encountered during the design phase, including RF hardware design, integration of the network stack with the metering node and design of the edge router. During the course of the project, they were able to validate the implementation of the standards using a packet tracer and were also able to calibrate the energy meter using standard instruments available in the laboratory. The project has potential for further expansion, for example it can be extended to three-phase energy monitoring in an industrial setting.

About the Use of Standards

As we have access to IEEE digital library and other resources in our institute, I regularly encourage my students to refer to the actual standard documents and RFCs and relate them with course material. This gives them an idea towards developing projects based on recent trends and also helps them outline their scope of research.

The idea of implementing 6LoWPAN was born out of guiding two groups of under-graduate and post-graduate students during their seminar. They were enthusiastic for exploring this standard further and to develop an application.

Dilip Kumar Kothari received his BE degree from Guru Ghasidas University, Bilaspur (MP) in 1984, ME degree in Digital Technique and Instrumentation from Devi Ahilya Vishwavidyalaya, Indore in 1989 and Ph.D. from Motilal Nehru National Institute of Technology, Allahabad in 2009.

He joined the Department of Electronics Engineering, SSVPS's College of Engineering, Dhule (MS) in 1986. In December 1997 he joined as Assistant Professor and currently holding the post of Professor in Electronics and Communication Engineering Department with Institute of Technology, Nirma University, Ahmedabad (India). His research interests are in the area of Optical and Wireless Networks. He is presently supervising the doctoral studies of five candidates

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Best of Student Application Papers

In each issue we publish selected "Best of Student Application Papers." These papers are written by students who have received IEEE Standards Education Grants to help with projects that include the use and implementation of technical standards.

Wireless Energy Monitoring Using 2.4 GHz 6LoWPAN

By Mitul Vekariya, Mohit Agarwal, and Parav Nagarsheth

Electronics and Communications Engineering Branch, Electrical Engineering Department, Institute of Technology, Nirma University, Ahmedabad, India

Third Quarter 2013

Abstract— Over-use and mismanagement of electrical energy is a prevalent problem in the contemporary world. To overcome this potentially crippling flaw in electricity distribution, an effective monitoring system has to be developed. This paper proposes an integrated hardware and software solution for wireless monitoring of energy consumption of the end-user through a network of metering nodes connected to every device. To achieve scalability in this network, 6LoWPAN is the protocol of choice. It combines IPv6 with an efficient header compression scheme to meet the stringent requirements of 802.15.4 data payload. The steps involved in design and development of the network and the nodes have been elaborated. The feasibility of this design has also been scrutinized.

Index Terms — Energy Monitoring, 6LoWPAN, 802.15.4, Wireless Sensor Networks

I. INTRODUCTION

In 2011, the world consumed an unprecedented 18,466 TWh unit of electrical energy [1]. To meet the demands of the developing world, this figure can be expected to increase manifold [2]. Thus, the need to mitigate the pressure on the Earth's natural resources has never been higher. One obvious solution is to switch to non-conventional energy sources like the wind energy and the solar energy. However, such technologies are still under-development, and eventually don't address the perpetual problem of reckless energy wastage. A scalable model needs to be developed that attempts to solve the challenges of energy conversation.

Electrical energy monitoring and analysis systems have been around for decades. However, they have primarily been present at the grid level, to regulate the supply of electric power to large areas like cities, districts or industrial hubs. These systems are unable to check usage at the consumer level, where maximum wastage is likely to occur. This can be effectively solved by deploying nodes which monitor electric power consumption of consumer devices.

Figure 1 illustrates the block diagram of an energy monitoring network. Everyday appliances like lights bulbs and by-extension, sockets become nodes which have the ability to measure line voltage, current and active energy consumed by them. On the other hand, an edge router (coordinator and internet gateway) is responsible for creating a network, acquiring the metered data from the nodes and sending application layer packet information to an HTTP server for display on the user's device.

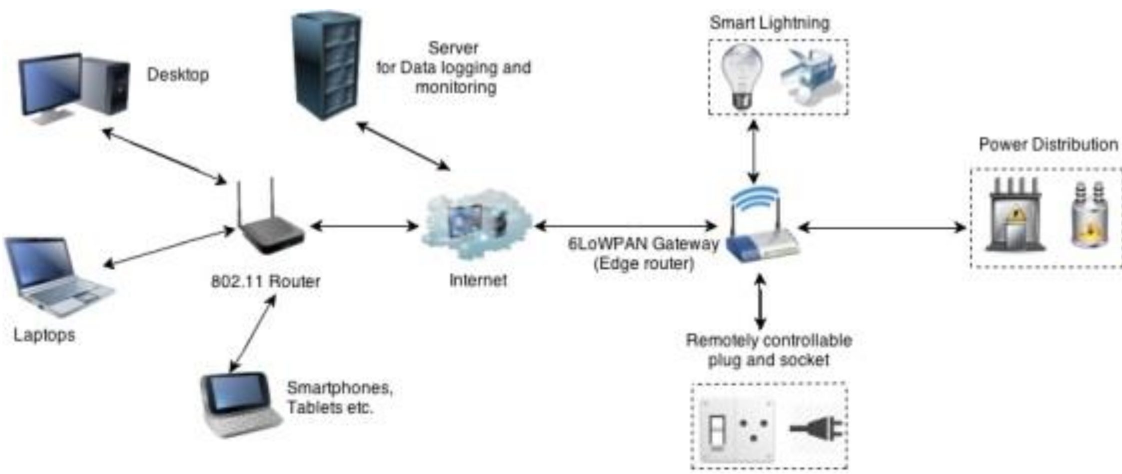

Figure 1: Block diagram of an energy monitoring network

The following standards have been discussed and implemented in the application:

- IEEE 802.15.4 MAC and Physical layer definition for low power and low data rate communications [3]
- IPv6 over Low-Power Wireless Personal Area Networks (6LoWPAN) [4]
- Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPAN-ND) [5]

Implementation of the above standards has been discussed in detail in further sections.

The rest of the paper is organized as follows:

The application overview along with salient features of IEEE 802.15.4 and 6LoWPAN standards are described in section II. Section III presents design of hardware and software followed by testing and evaluation of the integrated design is given in section IV. Final conclusion and a brief about further work scope are given in Section V.

II. APPLICATION OVERVIEW

A. Energy Metering

Figure 2 illustrates the sampling block of the energy metering IC. The IC has two fully differential voltage input channels, which sample the buck converted voltage and current waveforms. The maximum input voltage to the differential Programmable Gain Amplifiers (PGA) in the channels is limited to ±500mV. Hence, external current and voltage transducers are required to sample load current and line voltage. An external analog low-pass filter (RC) at each channel prevents aliasing, an artifact of all sampled systems [6].

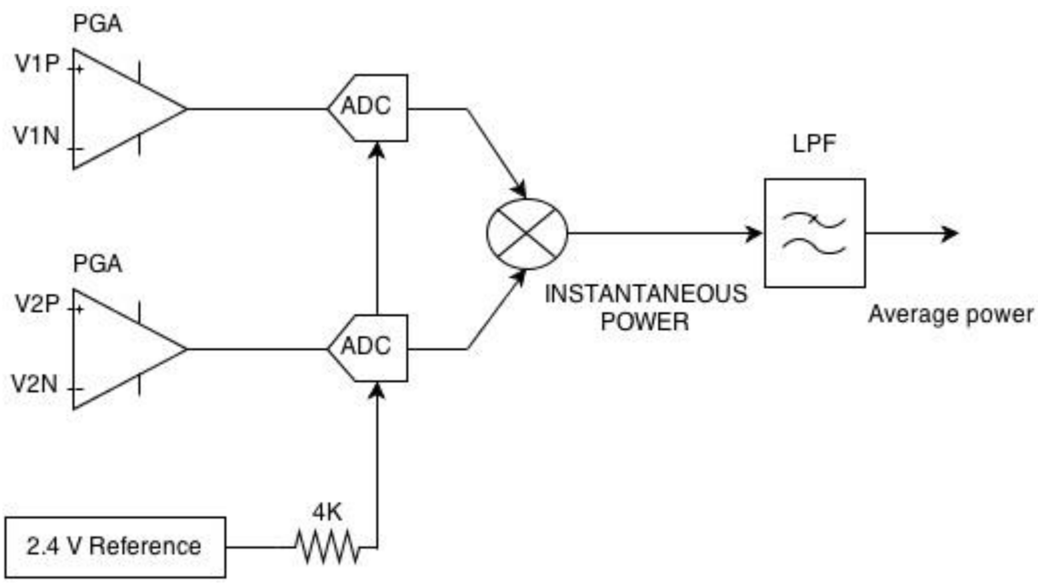

Figure 2: Active power calculation

The analog-to-digital conversion (ADC) is performed using two oversampling sigma-delta modulators. A 24-bit register for each channel stores the instantaneous value of voltage and current. The corresponding root mean square values are calculated by squaring the instantaneous values, averaging and then obtaining the square root. These are stored in a separate register. The waveform and the rms registers have corresponding offset registers to compensate for possible errors during conversion and sampling.

To obtain the real active power, the current and voltage waveforms are multiplied. The dc value of the instantaneous power signal is extracted using a low pass filter to obtain the active power information. The active energy is obtained by further accumulating the value of active power in the active energy register.

B. IEEE 802.15.4

IEEE 802.15.4 standard specifies the physical (PHY) and Media Access Control (MAC) layer for Low Power Wireless Personal Area Networks (LoWPANs). IEEE 802.15.4 over 2400 MHz defines the PHY layer for this application [3]. This standard has been designed keeping in mind the constraints of low-cost, low-power devices, with less emphasis on overall throughput.

The complete PHY layer and a partial MAC layer have been implemented on a single System-on-Chip (SoC). The PHY layer of the 802.15.4 identifies the use of several modulation schemes in several frequency bands. The 2450 MHz (2.4 GHz) frequency band is license-free worldwide, and hence is the ideal band for this application. The modulation scheme specified for the 2.4 GHz band is Orthogonal-Phase Shift Keying (O-QPSK) with 16-ary orthogonal signals. The PHY layer is also responsible for energy management, channel selection, data transmission and reception and link quality indication (LQI) for received packets. It also facilitates low power operation wherein a node may remain inactive for longer periods compared to the duration for which it is actually communicating, thereby saving power and reducing channel traffic. It only consumes up to 1% power compared to IEEE 802.11 (Wi-Fi) and is significantly simpler to integrate with embedded systems.

The MAC layer of the IEEE 802.15.4 standard provides an interface between the higher level layers and the PHY layer. It also manages several critical tasks like generating network beacons, synchronizing the beacons, PAN association and disassociation, frame validation and checksum validation as well as collision detection schemes like Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA).

The IEEE 802.15.4 MAC layer offers a substantial flexibility with respect to its implementation, while allowing many of its features to be reused in the upper layers. For e.g., in this application, the use of beacon frame format has been purposefully avoided, leaving association and disassociation events to the upper layers. At the same time, the various addressing schemes of the MAC layer have been thoroughly used to assign addresses by the upper layers. It is not uncommon to find instances of both 16-bit and 64-bit addressing schemes in the MAC layer of this application. The general frame format of the MAC layer is shown in Fig. 3 [3].

Despite the obvious advantages of IEEE 802.15.4 with respect to power consumption and ease-of-implementation, it is not suitable for applications which require high data throughput like browsing, streaming, file transfer etc. Hence, it is mainly deployed in sensor networks or low data-rate networks.

Octets:2	1	0/2	0/2/8	0/2	0/2/8	variable	2
Frame control	Sequence number	Destination PAN identifier	Destination address	Source PAN identifier	Source address	Frame payload	Frame check sequence
		Addressing fields					
MAC header						**MAC payload**	**MAC footer**

Figure 3: General MAC frame format

C. 6LoWPAN

With the advent of Internet Protocol, Version 6 (IPv6), the possibility of making the internet home to a large sphere of embedded devices has become a reality [7]. IPv6 can assign 3 x 1038 unique addresses, a huge number considering that the small address space of IPv4 (only 4.3x109 unique addresses) is about to exhaust only now [8]. Thus a large amount of spare addresses can be used to identify the aforementioned embedded devices, on the internet.

6LoWPAN is a protocol definition to enable IPv6 packets to be carried on top of low power wireless networks, specifically IEEE 802.15.4[4]. However, directly transporting IPv6 packets in the 802.15.4 payload is not possible, chiefly due to the following reasons:

- 802.15.4 addressing modes have no support for a 128-bit address space [3]
- The Maximum Transmission Unit (MTU) of IEEE 802.15.4 is 127 bytes, compared to the MTU of IPv6, viz. 1280 bytes [9]

The above constraints can be met by efficient header compression and upper layer optimization schemes [9]. The OSI model of 6LoWPAN in Fig. 4 illustrates the presence of an additional 6LoWPAN adaptation layer between the data link layer and the network layer [10].

Aside from a large address space, 6LoWPAN introduces several desirable features like auto-configuration and statelessness, These features can be exploited for coordination of hundreds of devices in a LoWPAN It also ensures interoperability in other IP network links like Wi-Fi, Ethernet, Serial lines etc., with the option of a simple tunneling mechanism to translate IPv6 to IPv4 [4]. In comparison with other upper-layer 802.15.4 protocols like Zigbee, following are some of the features that make 6LoWPAN to perfectly use with Internet Protocol (IP).

1) Header Compression: The internet protocol header compression (IPHC) is implemented in the adaptation layer. The header compression scheme defined in the initial standard definition (RFC4944) has now been obsolete by RFC6282. The dispatch field distinguishes 6LoWPAN packet from other IEEE 802.15.4 packets [11]. The following fields are either compressed wholly or partially:

a) Source IP: The 64-bit prefix can be assumed either link-local or specified inline. The 64-bit interface identifier (IID) form the 64-bit or 16-bit short address specified in the 802.15.4 header. It is normally derived from the Extended Unique Identifier (EUI-64), i.e. the physical address; or can be an address specified by a router.

b) Destination IP: Same as source IP compression.

c) Hop Limit: Useful in compression of ICMPv6 messages.

d) Next Header: Can be compressed for pre-determined headers or carried inline like UDP [11].

e) UDP Ports: Compressed to a 4-bit field to specify ports from 61616 to 61631.

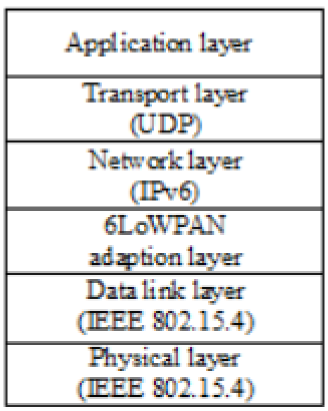

Figure 4: 6LoWPAN Model

2) Neighbor Discovery Optimization (ND): It is one of the unique features of IPv6. 6LoWPAN-ND defines several optimization schemes for low data rate systems. Figure 5 show the steps required to configure a 6LoWPAN node (6LN), 6LoWPAN router (6LR) and a 6LoWPAN border router (6LBR). A 6LN on power-up assigns itself a link-local address, derived from its EUI-64, which is assumed to be globally unique. For configuration, it periodically transmits a router solicitation (RS) message to all the router multicast address FE80::2 until it receives a router advertisement (RA). The RS packets are transported as link-layer broadcast packets in 802.15.4, since there is no multicast support [5]. The RA contains a source link address option (SLLAO) which contains the link-layer address of the 6LR. To save power, the 6LR transmits RA messages only on receiving RS. After reception of the RA, the 6LN transmits a neighbor solicitation (NS) message to register a 16-bit short address it assigned to itself. The 6LR forwards this message to the 6LBR to perform duplicate address detection (DAD). So, node doesn't require to join solicited node multicast address [5]. The 6LBR returns a duplicate address confirmation (DAC) message which either approves or rejects the requested address. On receiving the neighbor advertisement (NA), the 6LN is officially registered with the network.

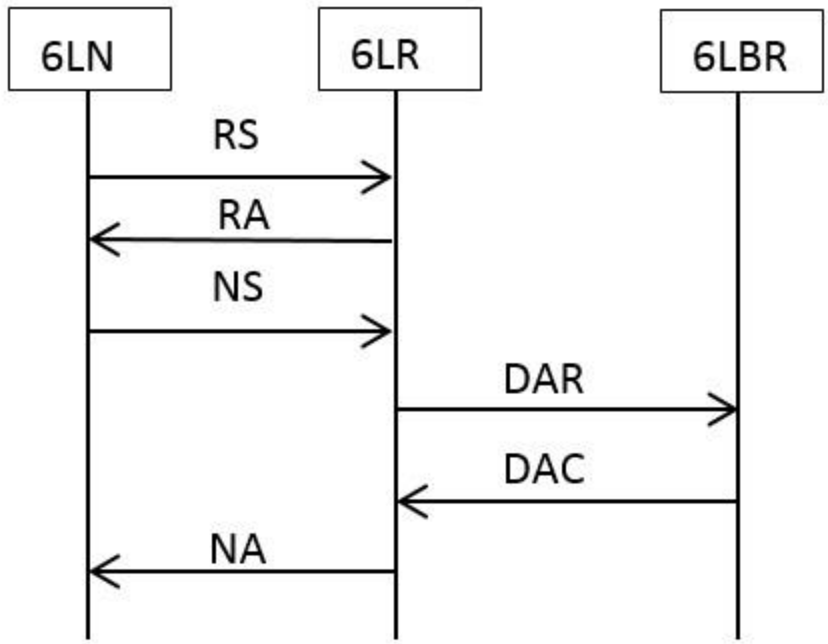

Figure 5: 6LoWPAN Neighbor Discovery

III. DESIGN AND IMPLEMENTATION

The design of the hardware and software can be decomposed into several blocks. This section provides a detailed outlook of the steps involved in designing, debugging and finally integrating several blocks of the application.

A. Node Hardware Design

The node hardware design involves designing the schematic, selecting the components, designing the layout, fabricating the PCB, soldering and testing. Figure 6 shows a simplified block diagram of the actual node.

1) Power Supply: A large number of components on the PCB require low-voltage DC supply. The input AC (110-230V) is converted to 12V DC using an isolated Switched Mode Power Supply (SMPS). Two low-dropout linear regulators in cascade provide 5V and 3.3V to low-power circuitry. A wide range of decoupling capacitors are used to remove the effects of supply ripple in sensitive parts of the hardware. On the supply side, a 5A slow-blow fuse protects against short-circuits. Similarly, a metal oxide varistor (MOV) protects against high voltage transients.

2) Energy Metering IC: The ADE7753 is a single phase multifunction energy metering IC from Analog Devices. As discussed before, it incorporates all the signal processing required to perform line voltage measurements, active energy measurements and rms calculations on voltage and current [6]. A 1:500 turn current transformer with a 10 ohm load converts the load current into a voltage signal for sampling. A 1 mega ohm resistor divider network across the line voltage delivers input to the voltage channel of the IC, as shown in Fig. 6. In a mixed-signal design, interference of analog and digital signals have a detrimental effect on signal conversion. Hence, to minimize the return paths, the PCB has separate analog and digital ground planes, tied together at a single point. The analog ground plane is used as the reference for the anti-aliasing filters, voltage and current transducers, and the analog-to-digital converters. The digital ground plane is used as reference for the rest of the components, which use digital signals. The ADE7753 is equipped with a 3-wire serial peripheral interface (SPI) for communication with an external microcontroller. This interface is used to read from and write to the internal registers on the ADE7753.

3) Application Processor: The application processor is an ATMEGA328P microcontroller from Atmel. It runs a program which is responsible for critical functions of the node, whilst acting as an intermediary to the network processor. The primary function of the processor is to read the values of active energy, rms voltage and current from the energy metering IC. These raw values are converted into readable SI units using an equation involving several constants: the equivalent value of the register for full-scale analog input and the respective transducer constants. The application processor can be used to debug and calibrate the energy meter from these values. The ADE7753 registers are read periodically every 500 milliseconds, conforming to the update rate of the IC. These values are displayed on a 16x2 LCD interfaced with the ATMEGA328P. The application processor also controls a relay, capable of switching power to the AC load. Hence, providing a method to monitor and control the load. All functions and features of the application processor are available to the network processor over a 2-wire Universal Asynchronous Receiver Transmitter (UART), using a simple protocol. If required, the ATMEGA328P can store the metered values on an on-chip EEPROM for data retention in case of a power failure.

4) Network Processor: The function of the network processor is performed by STM32W108, a fully integrated SoC which integrates a 2.4 GHz, IEEE 802.15.4-compliant transceiver and a 32-bit ARM Cortex-M3 microcontroller, from STMicroelcetronics. It runs off an external 3.3V supply for powering the controller and uses an in-built 1.8V regulator for the radio. It claims to be extremely power efficient with a 1uA power consumption during deep sleep modes, required to retain the RAM contents. Many transceiver components like the VCO, loop filter and power amplifier are integrated within the SoC. However several external components like the balun, filter and antenna are connected to the SoC externally via PCB traces [12]. To keep electromagnetic interference (EMI) to a minimum, care was taken to choose the smallest possible footprint for each external component (including capacitors and resistors). As a result, soldering the surface mounted (SMD) components and the SoC itself was a significant challenge, requiring several days of trial-and-error to achieve acceptable performance. The authors recommend the use of professional soldering equipment in case of unavailability of suitable ready-made modules for a similar application [13]. The network processor accepts metering data from the application processor over the UART interface and parses external requests to the application processor, to switch the load. It also runs a 6LoWPAN stack with implementations like neighbor discovery in the network layer and universal datagram protocol (UDP) in the application layer.

B. Application Software

The application software was developed on the Arduino IDE, using the Arduino libraries. For atomicity and extensibility, the code is logically divided into:

- ADE7753 libraries, to provide a low-level API to set various parameters of the IC and read metered values.
- Conversion functions, to convert raw sampled and/or processed values into SI units.
- Application Loop, to poll the UART interface and to send parsed data to the network processor.

C. Edge Router

The edge router is:

- A PAN Coordinator in the 802.15.4 network.
- An internet gateway for connectivity to global networks.

It runs on a small open source computing platform, the Beaglebone. To provide 802.15.4 PHY and MAC support, the Beaglebone is interfaced with a MRF24J40MC 802.15.4 module from Microchip, via SPI. The edge router is connected to the internet via Ethernet. The code for the edge router is written with a set of non-OS abstraction libraries for the Texas Instruments AM335x microprocessor, termed as Starterware. The TCP/IP functionality is provided by a slightly modified port of the lwIP stack. The 6LoWPAN stack runs side-by-side the lwIP stack. Dual stack model is implemented in edge router [15]. To handle concurrent requests, most of the code is interrupt driven.

The edge router keeps a cache of the addresses of all nodes registered with it. It also runs a web server to display the status of the nodes to the end-user, as shown in Fig. 9. To switch the load, the user can press a button on the web server and the relay on the corresponding node will be toggled.

D. 6LoWPAN Stack

The code for the 6LoWPAN stack is written in the C programming language. An interrupt-driven model is used to transmit and receive the packets. The packets to be transmitted and received are stored in separate buffers, space for which is statically allocated in memory. A static allocation is necessary in embedded systems with limited RAM, to optimize memory use at compile-time.

The primary functions of the stack are as follows:

1) Node Auto-configuration: An uninitialized node tries to solicit with a nearby router by broadcasting RS messages on the all router multicast address [5]. This activity is repeated until it receives an advertisement from the router. If no RA is received after a predefined number of times, the node gives up and goes to sleep. This is the only explicitly called function in the entire stack. The entire procedure is shown in Fig. 7.

2) Packet Reception: If a valid 802.15.4 packet is received, the MAC layer copies the packet into a buffer and generates an interrupt. The interrupt handler checks the packet for a 6LoWPAN dispatch field and if found, forwards it to the upper layer functions. These functions extract data from the packet and call the corresponding event handlers, if a response is required. For e.g. on reception of the RA, the 6LoWPAN stack calls eventhandler_NS().

3) Packet Transmission: A packet transmission is normally required by one of the event handlers. The data of each packet is assembled byte-by-byte in the event handler by calling various functions for generating the IEEE header, the IPHC header and the ICMPv6 or UDP headers. Finally the total length of the packet is calculated and the packet is transmitted via CSMA-CA.

The 6LoWPAN stack has several data structures which contain elements of packet frames specified in the RFCs and IEEE 802.15.4. The data in each packet can be read/write by pointers to these structures. The packet buffers are ordered in the format given by the IEEE 802.15.4 and 6LoWPAN standards. This facilitates a simple but intuitive method to control various parameters of different packet frame formats, e.g., the ICMP_struct and the UDP_struct may be pointing to the same address in memory. However, they are used to make completely different packets. The memory location they are pointing to can be changed by a simple offset variable.

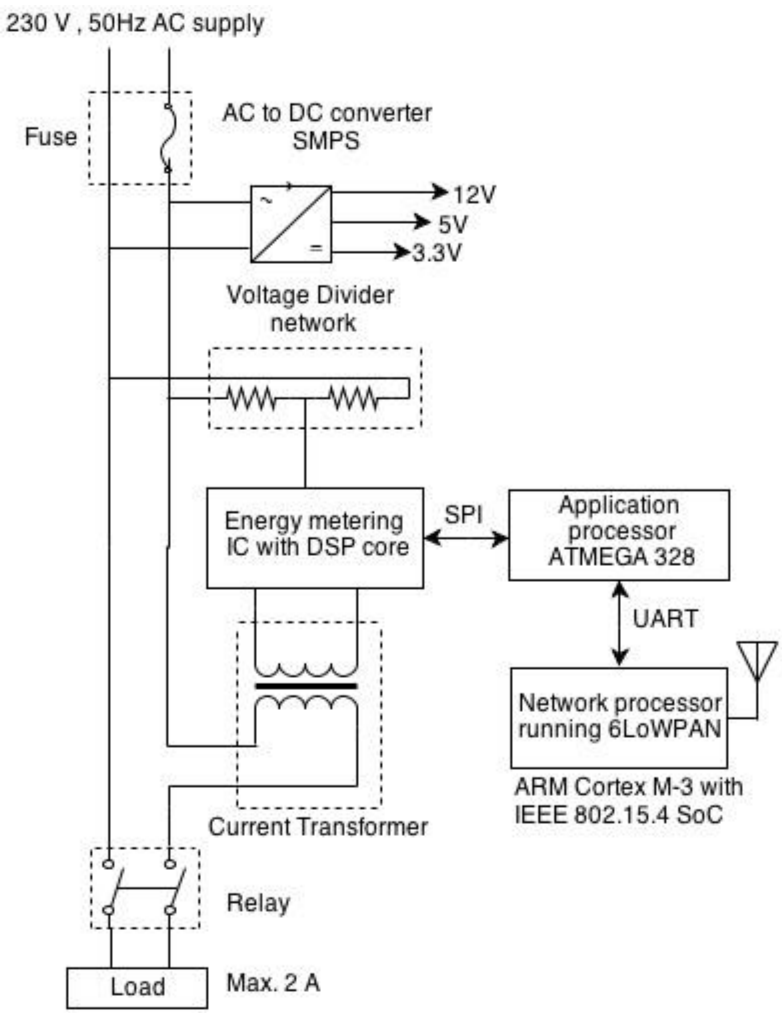

Figure 6: Block diagram of energy metering node

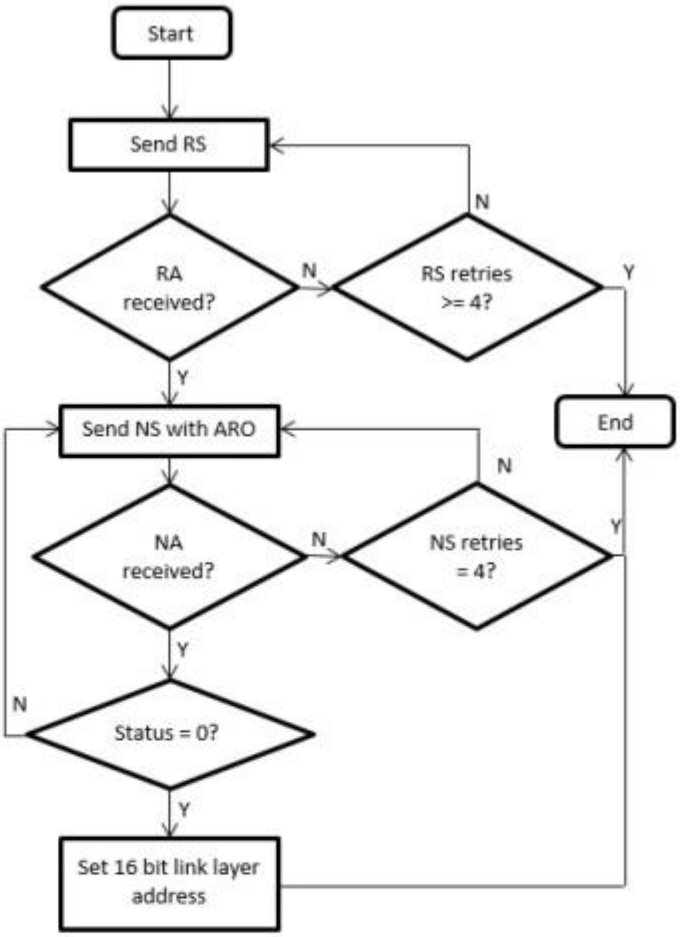

Figure 7: 6LoWPAN Node Auto-configuration

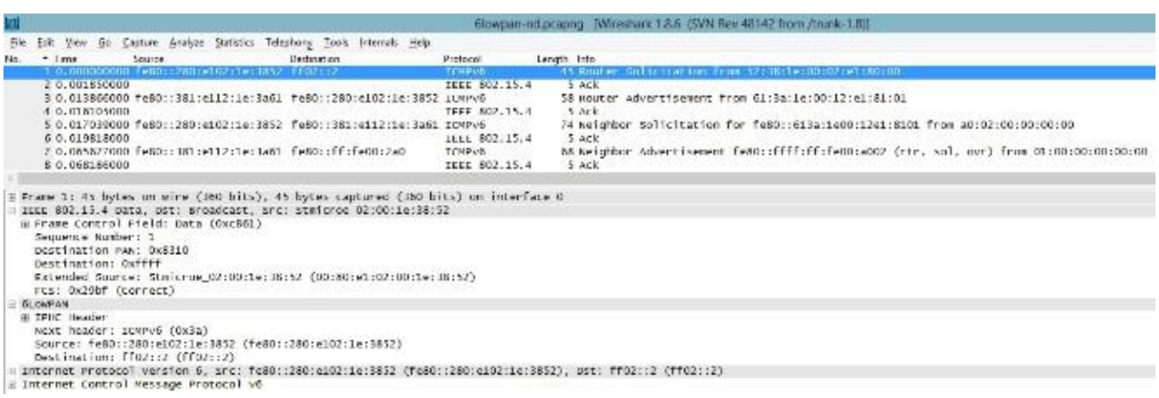

Figure 8: Wireshark packet tracer screen capture

IV. TESTING AND RESULTS

A. PCB Testing

The final assembled PCB is shown in Fig. 9. The testing of the PCB was done in batches. Initially, the RF circuit was completely tested by transmitting and receiving packets to and from a reference transceiver. The range of the node could be ascertained to 20 m in closed space and 50 m in open space. After satisfactory RF performance, the circuit pertaining to application processor (ATMEGA328p) was tested. The LCD interface and the serial communication peripherals (UART) between ATMEGA328p and STM32W108 were verified. Further, the AC power supply block and the metering circuit with an external load were tested. The external load was a lamp bank with variable current consumption. Some raw energy metering data was observed before calibration, which is detailed in the next section.

B. Meter Calibration

Meter calibration is an important phase in development of any energy meter. It is desired by both, the grid company and the end-user to ensure correct billing for the energy consumed. For rms calibration, precision AC voltmeter and ammeter were used with a steady load. Slight offsets were adjusted with the help of internal offset registers in ADE7753. Both errors were minimized to be within 1% of the actual values. Table 1 illustrates the measured and reference readings obtained by connecting a lamp bank as load.

Table 1: Reference readings and Measured readings for Vrms and Irms

Reference Voltmeter Reading (V)	Node Reading (V)	Reference Ammeter Reading (A)	Node Reading (A)
220-233	218-230	0.20	0.20
220-233	218-230	0.67	0.66
220-233	218-230	1.01	1.00

The ADE7753 also has an energy-to-frequency converter, which can be used to verify the energy calibration. Here, the output frequency is proportional to the active power or energy consumed by a steady state load. A meter constant is subsequently defined, in terms of number of ticks (frequency) per kilowatt hour (kWh). Henceforth, ATMEGA328p counts the number of ticks and increments kWh where the number of ticks equals the meter constant. The meter constant was derived by calibrating the node against an accurate energy meter.

C. Standard Validation

Validity of any standard implementation is paramount to ensure interoperability with other devices running the same standard. Figure 8 shows the screen grab of Wireshark, an open source packet tracer and identifier [14]. To capture the transmitted packets from the node, an 802.15.4 module (RFC-KIT) from STMicroelectronics, was configured as a packet sniffer. It can be seen that the first message is an RS, transmitted by the node with a destination ff02::2 (all-router-multicast). The router sends an automatic acknowledgement in about 1.8 ms and a following RA message within 14 ms. The entire node configuration (duplicate address detection and assignment of IP address) is completed within a mere 68 ms of the initial power-on.

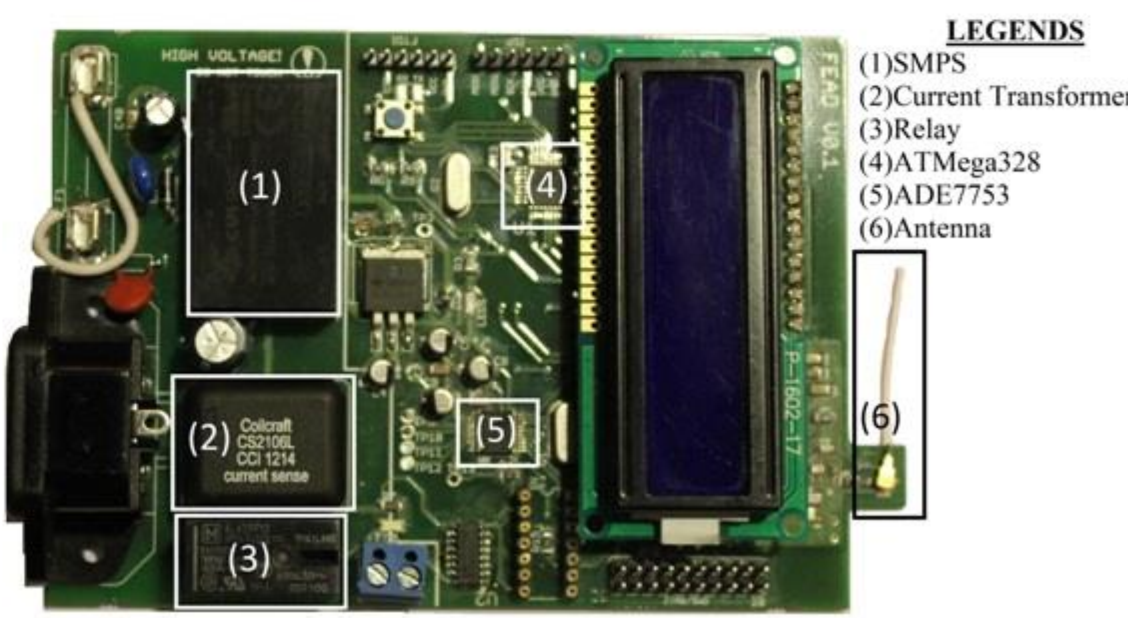

Figure 9: Energy Metering Node

V. CONCLUSION AND FUTURE SCOPE

Energy monitoring through wireless meters represents a cost effective and feasible solution to the prevalent problem of energy misuse. The energy metering node is calibrated to measure energy in kWh and transmits the same to an edge router using 6loWPAN protocol. 6loWPAN advocates its superiority in low data rate and low power networks over other existing protocols owing to its compatibility with IPv6 that allows for large number of hosts. It has a significant advantage over Zigbee in these aspects; however it is still not in very wide use. The hardware for the node fulfilled most of the requirements of a typical energy meter. However, improvements could be made to improve noise resilience and to include a tamper-proof seal to prevent data manipulation.

This node has huge potential for filling the existing gaps in energy management. It can be made much user friendly such that any device can be integrated with the node and the corresponding energy consumption measured. In fact, it can be envisioned as a stepping stone towards Home Automation. Additional features can be added to the node like allowing the user to control his devices using external factors like daylight, temperature, and peak demand periods etc. before deploying it in the consumer market. The 6LoWPAN standard can also be extended to include routing protocols, allowing a more global reach for these nodes.

ACKNOWLEDGMENT

The authors thank Dr. D.K. Kothari (Professor, Nirma University) for his incessant assistance and generosity towards the development of this project. A special thanks for Prof Mehul Naik for his invaluable help in developing the RF circuit. The authors are also deeply grateful to IEEE Student Application Grant for sponsoring their project which helped them in completing their project in time.

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Standards Education Grants for Student Projects

By Jennifer McClain, Program Manager, IEEE Standards Education

3rd Quarter 2013

The IEEE Standards Education Committee (SEC) continues to offers grants of US $500 for students (per project) and US $300 for faculty mentors to help complete senior, undergraduate or graduate projects. Projects may be for design, capstone, development or research in which an industry technical standard(s) was applied to complete the project.

Students who receive the IEEE Standards Education Grants must submit a final paper called a Student Application Paper. The final papers detail which industry technical standard(s) were applied (analyzed and implemented). Each paper highlights specific design choices in the application of various technical standards and describes the resulting product, process, or service.

Between 2009 and 2013, 180 grant applications were received from students at over 75 different colleges and universities worldwide. 108 grants were approved between 2009 and September 2013 and 59 Final Student Application Papers have been accepted so far and posted to the Student Application Papers website. Of course, many students are still working on their design projects and new final papers based on their work will be added once approved by the SEC.

The Standards Education Grants directly support the IEEE goal of actively promoting the integration of standards into academic programs. The volunteers on the SEC spend a significant amount of time reviewing grant applications and final paper submissions. For students participating in the grant program, it is an excellent way to receive extra funding for student projects, to learn about technical standards necessary for their career development, and to have their final papers peer-reviewed by an IEEE committee.

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For more information about the IEEE Standards Education Grants and how to apply, please visit the IEEE Standards Education website, but first read the following helpful articles from previous issues of this eZine for some guidance:

- Introduction to IEEE Standards Education Grants and Student Application Papers
- Applying for IEEE Standards Education Grants.

Each issue of the IEEE Standards Education eZine contains a "Best of Student Application Paper." Don't miss this issue's featured paper from Mitul Vekariya, Mohit Agarwal and Parav Nagarsheth, Wireless Energy Monitoring Solution Using 2.4 GHz 6LoWPAN.

All successfully accepted final papers are posted to the IEEE Student Application Papers website.

Jennifer McClain has been with the IEEE for sixteen years. She spent eight years with the IEEE Standards Association aiding working groups with the standards development process, editing standards, and as the Managing Editor of the Standards Information Network, publishing handbooks and guides to help with the implementation and understanding of standards. She is currently the Program Manager for IEEE Standards Education. Ms. McClain holds a B.A. in History and English from Western Michigan University, Kalamazoo, MI.

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Contributions

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Abstracts should be no longer than 500 words and final articles should be no more than 2,000 words.

Particular areas of interest include, but are not limited to:

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Final contributions should include a 100 word biography of the author(s) and a high-resolution (JPEG) picture. All illustrations must be provided in a high-resolution (JPEG) format. References to all copyrighted material must be properly cited.

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IEEE Standards Education eZine Editorial Board

Yatin Trivedi, Editor-in-Chief, is Director of Standards and Interoperability Programs at Synopsys. He is a member of the IEEE Standards Association Standards Board (SASB), Standards Education Committee (SEC), Corporate Advisory Group (CAG), New Standards Committee (NesCom), Audit Committee (AudCom) and serves as vice-chair for Design Automation Standards Committee (DASC). For 2012, Yatin was appointed as the Standards Board representative to IEEE Education Activities Board (EAB). He represents Synopsys on the Board of Directors of the IEEE-ISTO and on the Board of Directors of Accellera. He represents Synopsys on several standards committees (working groups) and manages interoperability initiatives under the corporate strategic marketing group. He also works closely with the Synopsys University program.

In 1992, Yatin co-founded Seva Technologies as one of the early Design Services companies in Silicon Valley. He co-authored the first book on Verilog HDL in 1990 and was the Editor of IEEE Std 1364-1995™ and IEEE Std 1364-2001™. He also started, managed and taught courses in VLSI Design Engineering curriculum at UC Santa Cruz extension (1990-2001). Yatin started his career at AMD and also worked at Sun Microsystems.

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Professor Harding's scholarship and engagement activities revolve around the development and application of American National and ISO standards dealing with Technical Product Documentation (TPD) as it broadly relates to product realization, green manufacturing and other technical aspects of product lifecycle management (PLM).

He is active on a number of American National standards developing committees, and chairs the US Technical Activities Group (TAG) to ISO. He is ASME vice-president for Standardization and Testing, overseeing development of American National Standards for fasteners, geometric dimensioning and tolerancing, metrology, tools, pallets, threads, gaging, plumbing fixtures, metal mill products, chemical pumps, instrumentation, performance test codes and others.

Internationally, he has served as a US Delegate to APEC and has served as the Head of Delegation to ISO Technical Committee meetings in North America, Asia, Oceania, and Europe. Currently he chairs the 62-country ISO/TC10 committee on Technical Product Documentation, whose Secretariat is based in Sweden. The committee writes worldwide standards for technical product documentation for PLM.

Dr. James Irvine is a Reader in the EEE Department at Strathclyde University in Glasgow. His research interests include resource management and security for wireless systems, and he works as Academic Co-ordinator within the Mobile VCE programme. Prior to this he worked on the ACTS MOSTRAIN project providing communication services to high speed trains. He holds four patents, with three more being pursued, and has authored two books. Technical Programme Chair of VTC2004-Spring in Milan, Dr Irvine was elected in 2002 to the Board of the IEEE VTS, where he is chair of the VTS Technical Advisory Committee, and President for 2008-9.

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In 2000 he received the IEEE-SA Standards Medallion for 'leadership and technical contributions to Ethernet networking standards' and in 2009 he received the IEEE Standards Association Standards Board Distinguished Service award 'For long term service to improve the operation and integrity of IEEE-SA governance'. David has a BEng (hons) in Electrical and Electronic Engineering from Strathclyde University, Glasgow, Scotland. He is a senior member of the IEEE.

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He chairs, or is a principal technical contributor to, US and international EMC standards organizations including ANSI ASC C63® (immediate past chairman), the Institute of Electrical and Electronics Engineers (IEEE), and the International Electrotechnical Commission's (IEC) International Special Committee on Radio Interference (CISPR). He was named chairman of CISPR in October 2007. He is a member of the IEC's Advisory Committee on EMC (ACEC) and the Technical Management Committee of the US National Committee of the IEC.

In November 2008 he was presented with the prestigious IEC Lord Kelvin award at the IEC General Meeting in Sao Paulo, Brazil. This is the highest award in the IEC and recognizes Don's many contributions to global electrotechnical standardization in the field of EMC. He is a life Fellow of the IEEE and an honored life member of the IEEE EMC Society (EMCS) and member of its Board of Directors, chair of its technical committees on EMC measurements and Smart Grid, vice president for standards, past EMCS president, and past chair of its standards development committee. He is also past president of the IEEE Standards Association (SA), past member of the SA Board of Governors and past member of the IEEE's Board of Directors and Executive Committee. He is also the Associate Director for Wireless EMC at the University of Oklahoma Center for the Study of Wireless EMC. Currently he is a voting member of the Smart Grid Interoperability Panel and its Testing and Certification Committee. In addition he is a focus leader on the NIST Electromagnetic Interoperability Issues Working Group which is providing EMC recommendations for Smart Grid equipment and systems.

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