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STANDARDS ASSOCIATION

INTRODUCTION TO IEEE INTERNET OF THINGS (IoT) AND SMART CITIES

Srikanth Chandrasekaran
Senior Director, IEEE SA

IEEE Government Engagement Program on Standards (GEPS)
Webinar | 15 April 2020

IEEE

IEEE - ADVANCING TECHNOLOGY FOR HUMANITY

The World's Largest Professional Association

Global Reach

- 420,000 Members

- 160 Countries

- 117,000 Student Members

- 46 Technical Societies and Councils

Technical Breath

- 1,800 Annual Conferences

- 4,000,000 Technical Documents

- 190 Top-cited Periodicals

- 1,300 Active Standards

Social Impact

- Global Public Policy

- Global Humanitarian Efforts

- Continuing Education & Certification

- Ethics in Technology

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STANDARDS ASSOCIATION

RAISING THE WORLD'S STANDARDS

ABOUT IEEE SA

Developing market relevant open standards and solutions:

- Advancing global technologies and technology platforms
- Promoting innovation
- Protecting public safety, health & wellbeing
- Contributing to a sustainable future

IEEE

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IEEE SA BY THE NUMBERS

1500+
STANDARDS & PROJECTS

340+
CORPORATE MEMBERS

7500+
INDIVIDUAL MEMBERS

34,000+
GLOBAL PARTICIPANTS

180+
GLOBAL AGREEMENTS

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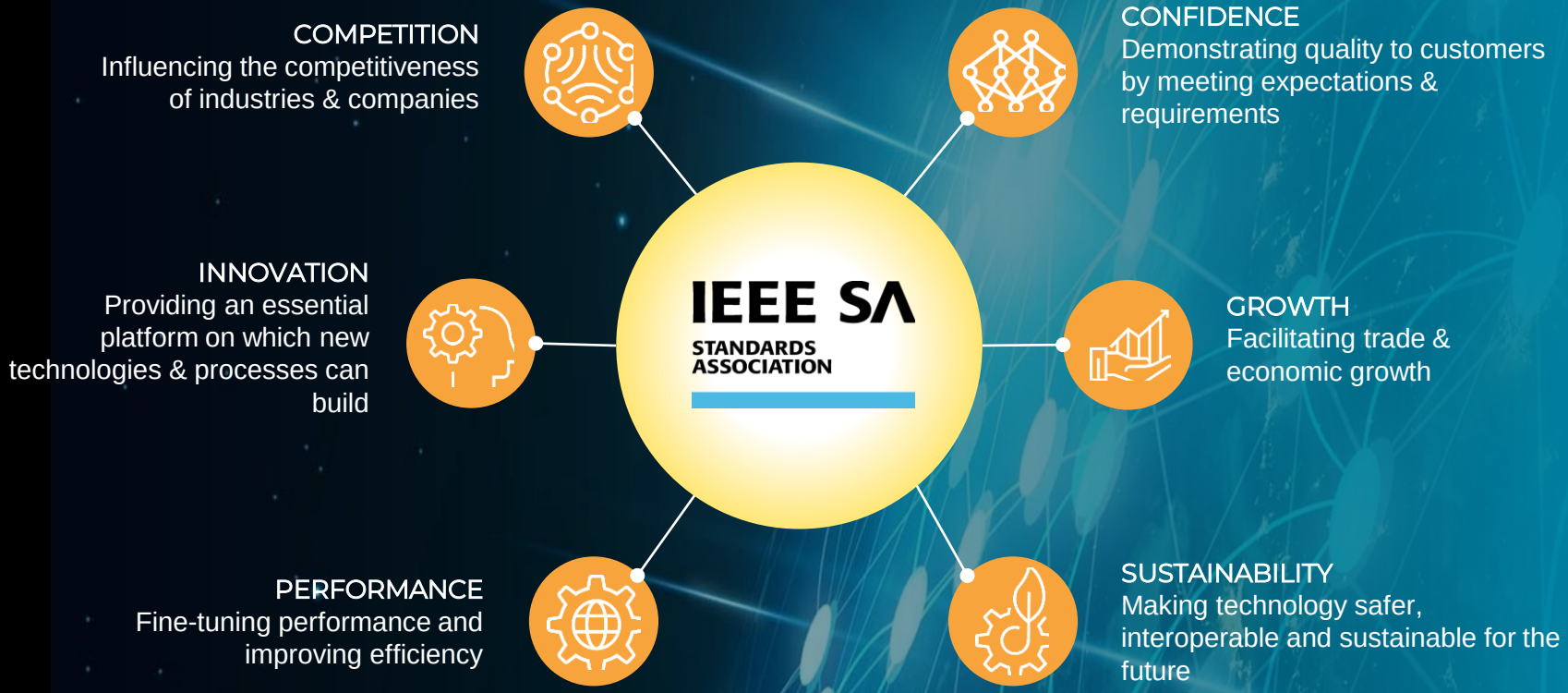
STANDARDIZATION OUTCOMES



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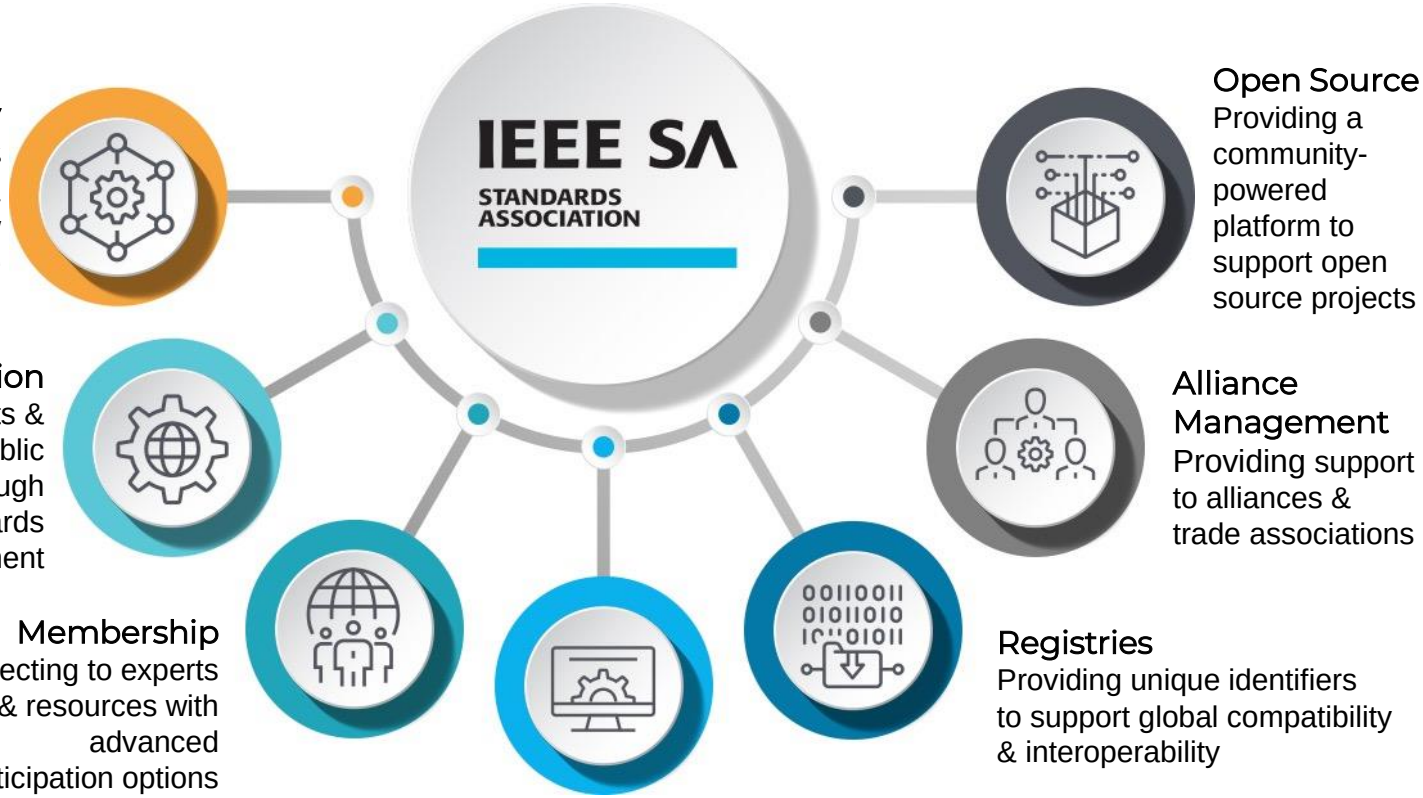
PORTFOLIO OF PROGRAMS & SERVICES



Industry Connections
Exploring & incubating new tech & its use

Open Source
Providing a community-powered platform to support open source projects

Standardization
Creating markets & protecting public safety through standards development

Alliance Management
Providing support to alliances & trade associations

Membership
Connecting to experts & resources with advanced participation options

Registries
Providing unique identifiers to support global compatibility & interoperability

Conformity Assessment
Providing confidence & assurance & accelerating market adoption

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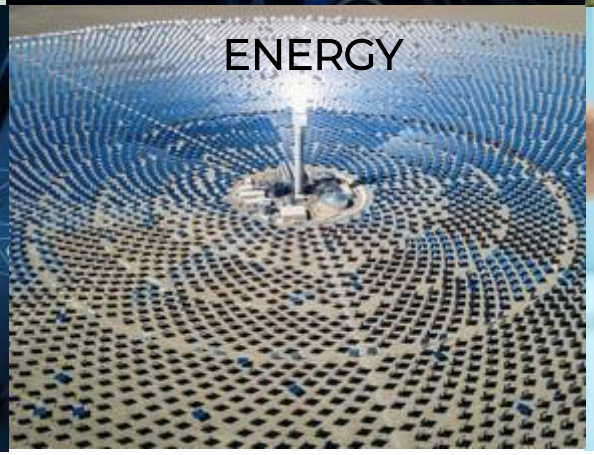
EXPANDING AREAS



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Home for Work in Emerging Technologies

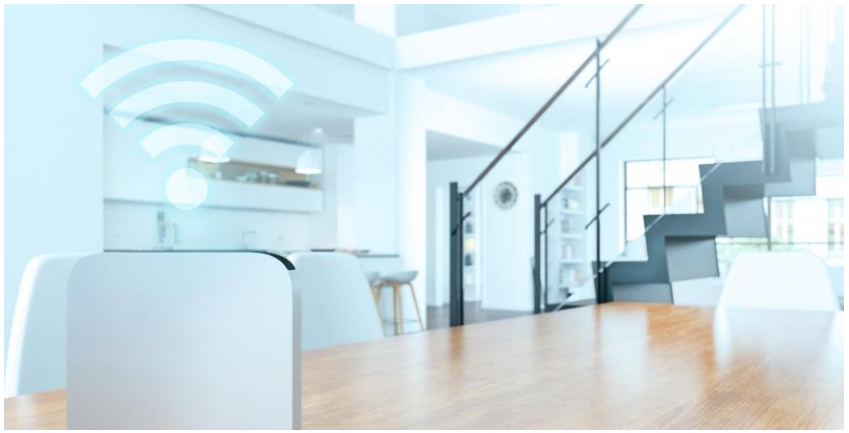
Industry Connections

- Incubation program for pre-standards work and related standards work
- Helps incubate new standards and related products and services by facilitating collaboration among organizations and individuals as they hone and refine their thinking on rapidly changing technologies
- Current examples include:
  - Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems
  - Computer Security
  - DC in the Home
  - Smart Glasses Roadmap
  - Smart City Compliance Indicators
  - Open Data
  - Augmented Reality in the Oil/Gas/Electric Industries

http://standards.ieee.org/develop/indconn/index.html

IEEE IoT

Objectives



The Internet of Things:

- Is one of the fastest growing technical areas
- Touches almost all Verticals of the World Economy, is a major investment for industry, government, and academia
- Has CAGR >20% year over year in the commercial marketplace

Within IEEE The purpose of the Initiative is to:

- Create a critical mass of offerings to impact on the future of IoT
- Grow a portfolio of activities
  - Achieve recognition and impact
  - Reach financial self sustainment for the portfolio
  - Provide for participation across IEEE
- Encourage strong collaboration and cooperation between IEEE Societies

IEEE IoT

A View of IoT

'The Internet of Things' is a general term that consists of many underlying ideas. The ideas are made real in a multitude of forms, and that can bring value to a broad range of products, services, processes, and end use applications.

What these have in common is:

- Deep digitization
- Use of an increasingly pervasive infrastructure
- Connectivity ranging from local to global
- Long lived protocols and standards
- Generation, storage, and analysis of "data"
- Exploitation of computing (algorithms, techniques, AI)
- **Closing the "control loop" by design**

When talking about the "Internet of Things" you will often come across:

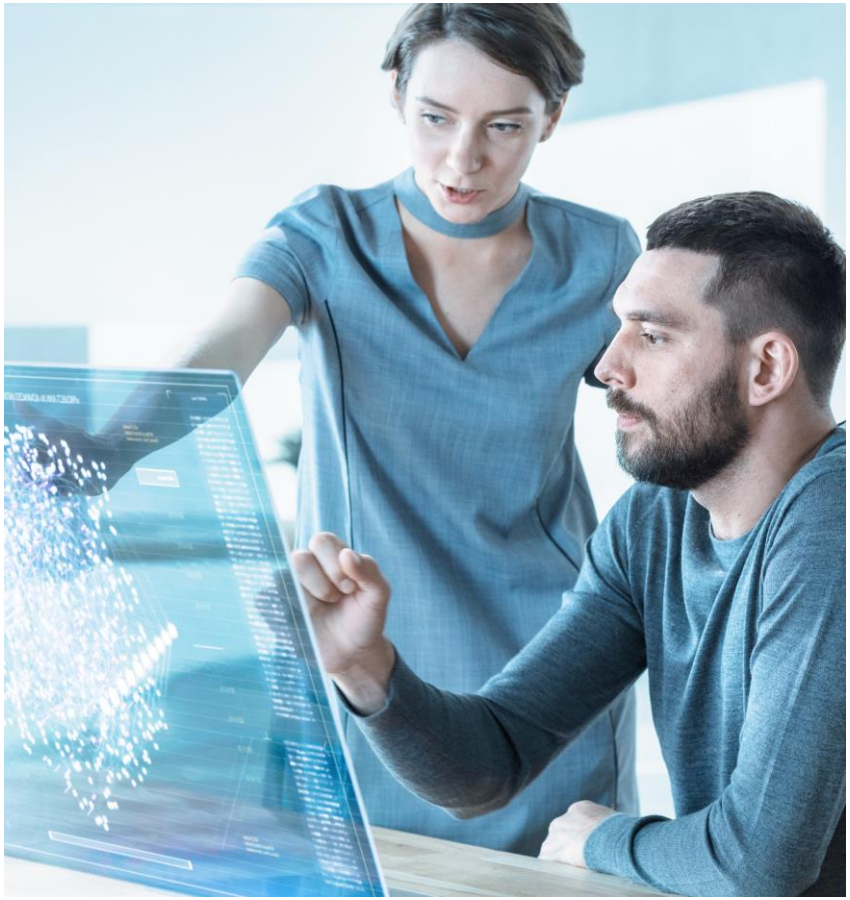
- Cyber-Physical Systems
- M2M – Machine to Machine Communications
- The Internet of Everything
- The Industrial Internet
- Industry 4.0
- The Network of Things
- The Connected World
- The Networked World

IEEE IoT

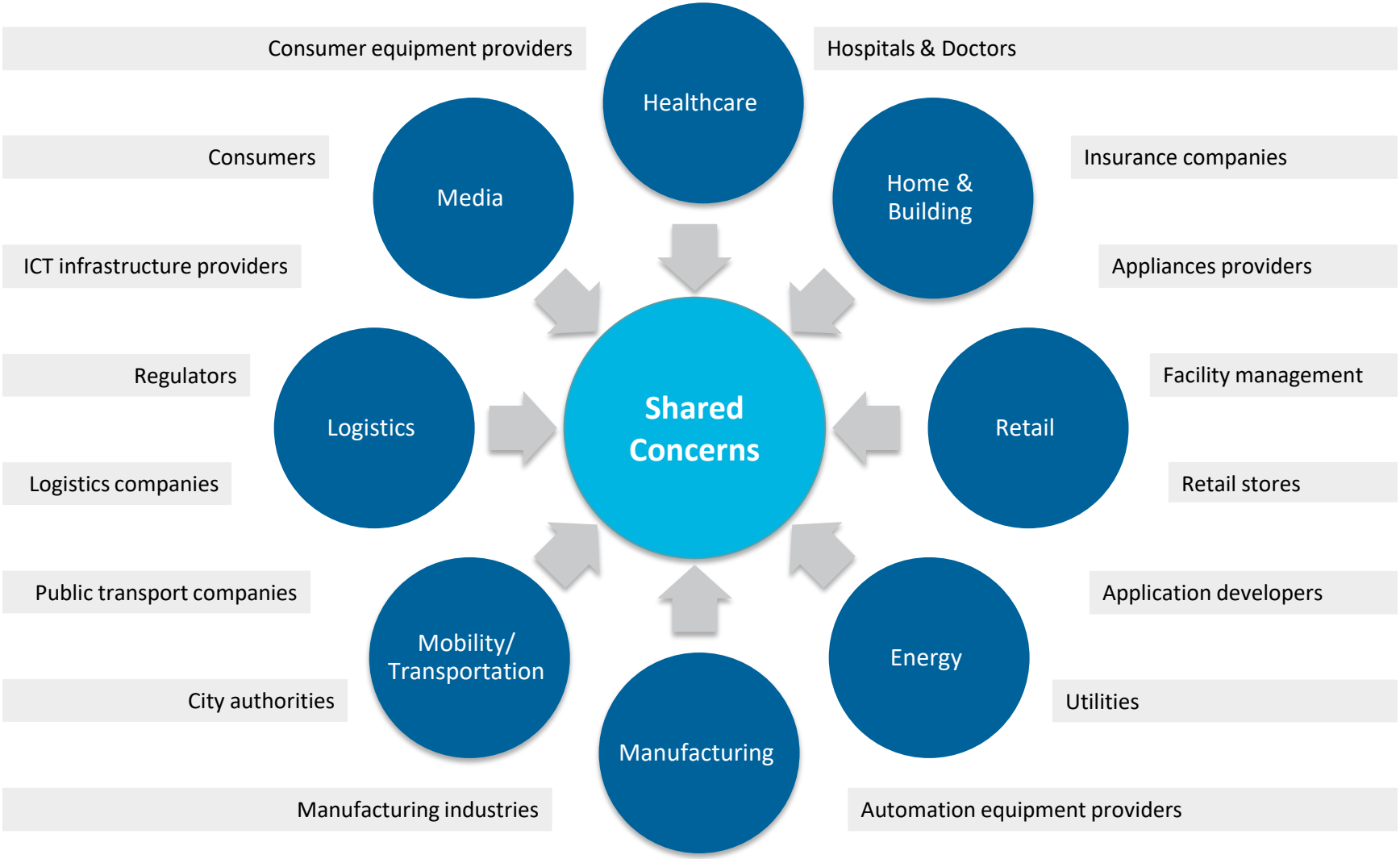
TIPPSS Framework

Non-functional requirements are taking center stage:

- **T**rust
- **I**dentity
- **P**rivacy
- **P**rotection
- **S**ecurity
- **S**afety



IoT: WHERE DOES THE INPUT COME FROM?*



* Due to the diversity of IoT application areas only selected domains and stakeholders are shown.

THE IMPACT OF IoT

IEEE Internet of Things

BILLIONS OF DEVICES

- More then 50 billion in 2020
- Heterogeneous architectures
- Big Dates and broadband communications

Source: Intel

MANY APPLICATION DOMAINS

- Consumers (i.e., wearable, home automation, wellness)
- Commercial (i.e., retail, building, logistics)
- Industrial (i.e., manufacturing, energy, transportation)
- Public Sector (i.e., Smart Cities and regions, public safety, security, healthcare)

Source: Beecham

DIFFERENT BUSINESS APPROACHES

- Intelligent services
- Open ecosystems
- Different value chains
- Many different business models
- New actors (e.g., Makers)

Source: Freescale

IEEE 802™

ALL THOSE DOTS…. DECODER RING

IEEE 802. 1™	Bridging and Architecture
IEEE 802. 3™	Ethernet
IEEE 802.11™	Wireless LAN (WLAN)
IEEE 802.15™	Wireless Personal Area Network (WPAN)
IEEE 802.16™	Broadband Wireless Access (BWA)
IEEE 802.18™	Radio Regulatory TAG
IEEE 802.19™	Coexistence
IEEE 802.21™	Media Independent Handover
IEEE 802.22™	Wireless Regional Area Networks (WRAN)
IEEE 802.24™	Vertical Applications TAG

IEEE 802™: BASIS FOR ALL THINGS 'CONNECTED'

WiFi Now Has Version Numbers!!

Wi-Fi 4 is IEEE 802.11n™, released in 2009.

Wi-Fi 5 is IEEE 802.11ac ™, released in 2014.

Wi-Fi 6 is the new version, also known as IEEE 802.11ax™. Scheduled for release in 2019.

- Higher speed – potentially 40% higher (but)
- Better performance in highly congested areas
- Longer Battery Life – Target Wake Time (TWT)

This will also help with low-power "Internet of Things" devices that connect via Wi-Fi.

IEEE 802™: 'KEEPING THE WORLD CONNECTED'

2020 – 40th Anniversary of IEEE 802™

- This year marks the **40th Anniversary of IEEE 802™** and the global achievements of thousands of innovators whose leadership and participation in IEEE 802™ working groups have paved the way for technological connectivity in how people live, work and communicate.
- The founders of the IEEE Local Area Network Standards Committee (LMSC) began discussing standardization opportunities in 1979, submitting a project proposal *"Local Network for Computer Interconnection"* through the IEEE Computer Society to IEEE in August 1979 that was **formally approved by IEEE on 13 March 1980**.
- Currently, the IEEE 802™ family of standards consists of **71 published standards** with 54 under development.
- **The most widely used IEEE 802™ standards** are for Ethernet, Bridging and Virtual Bridged LANs Wireless LAN, Wireless PAN, Wireless MAN, Wireless Coexistence, Media Independent Handover Services, and Wireless RAN with a dedicated Working Group providing focus for each area.

IEEE 802™: TECHNOLOGIES ARE BUILDING THE INTERNET OF THINGS TODAY

802.11	Enabling innovation today: In-home devices, innovative applications
802.15	802.15.4 utility and in-building infrastructure
802.24	Smart Grid and IoT Vertical Market support
802.16	802.16s licensed narrowband for utilities, see http://www.fullspectrumnet.com/80216s-a-new/
802.21	802.21 defined component in smart home energy conservation and homecare application stack***

*** see https://echonet.jp/wp/wp-content/uploads/pdf/General/Download/data1_e.pdf

MARKET DEMANDS AND NEW TECHNOLOGY DRIVE IEEE 802.11™ INNOVATION

Demand for throughput

- Continuing exponential demand for throughput (IEEE 802.11ax™ and IEEE 802.11ay™, IEEE 802.11be™)
- Most (50%-80%, depending on the country) of the world's mobile data is carried on IEEE 802.11™ (WiFi) devices

New usage models / features

- Dense deployments (IEEE 802.11ax ™), Indoor Location (IEEE 802.11az™)
- Automotive (IEEE 802.11p™, Next Gen V2X), Internet of Things (IEEE 802.11ah™)
- Low Power applications (IEEE 802.11ba™)

Technical capabilities

- MIMO (IEEE 802.11n™, IEEE 802.11ac™, IEEE 802.11ay™) and OFDMA (IEEE 802.11ax™)
- 60GHz radios (IEEE 802.11ay™)

Changes to regulation

- TV whitespaces (IEEE 802.11af™), Radar detection (IEEE 802.11h™), 6 GHz (IEEE 802.11ax™, IEEE 802.11be™)
- Coexistence and radio performance rules (e.g., ETSI BRAN, ITU-R)

IEEE 802™: ADDRESSING EXPANDING MARKET NEEDS

New 802.11 Radio technologies are under development to meet expanding market needs and leverage new technologies

- **802.11ax – Increased throughput in 2.4, 5 (and 6) GHz bands. Increased efficiency.**
- 802.11ay – Support for 20 Gbps in 60 GHz band.
- 802.11az – 2nd generation positioning features.
- **802.11ba – Wake up radio. Low power IoT applications.**
- 802.11bb – Light Communications
- 802.11bc – Enhanced Broadcast Service
- **802.11bd – Enhancements for Next Generation V2X**
- 802.11be – Extremely High Throughput

IEEE 802.11ah™ (SUB-GHZ)

Use Cases Are Broad: Consumer, Industrial, Agricultural

Industrial Automation

- Smart robots with local imaging

Agriculture, Horticulture, City farming

- Large number of devices supported
- See: http://www.methods2business.com/applications

Process Automation

- Predictive maintenance, logistics, inventory tracking

Healthcare in hospital and home settings

Home and Building automation

- Energy and asset management
- Remote operation/self diagnosis
- Whole home coverage for battery operated sensors

Retail: Electronic shelf labels

IEEE 802.11ad™ (60 GHz), IEEE 802.11ax™ (2.4 GHz, 5(6) GHz), IEEE 802.11ay™

Technology Can Be Leveraged To Meet 5G Requirements

Today's 4G networks include IEEE 802.11™ technologies

- For offload: *"More traffic was offloaded from cellular networks (on to Wi-Fi) than remained on cellular networks in 2016"* (Cisco VNI)
- For Wi-Fi calling

Wi-Fi carries most public & private Internet traffic worldwide

- Between 50-80% depending on country

5G radio aggregation technologies will natively incorporate Wi-Fi

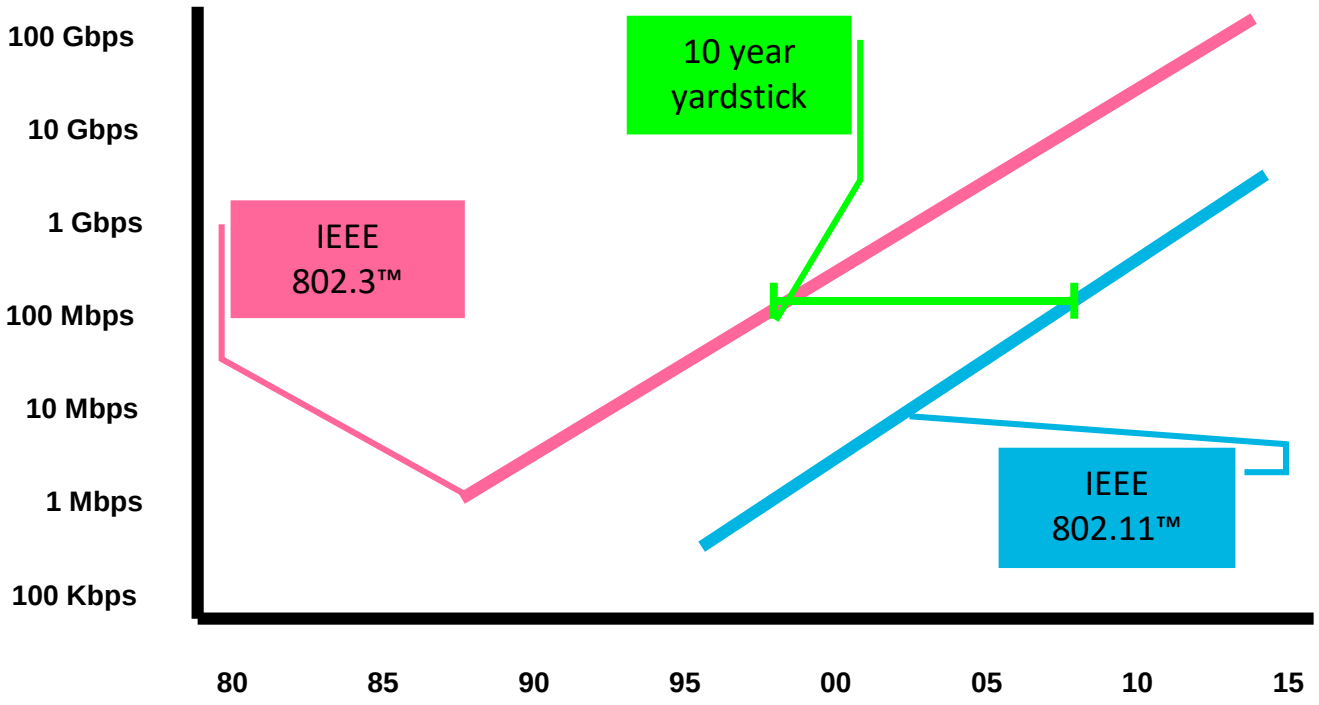
- IEEE 802.11™/Wi-Fi is a Peer Radio Access Technology in the 5G Architecture

IEEE 802.11ax™
8Gb/s (OFDMA, U/L MU-MIMO)
5G Hotspot Mobile Broadband

IEEE 802.11ay/aj™
60 GHz
n*20Gb/s (Aggregation+MIMO)
Device connectivity

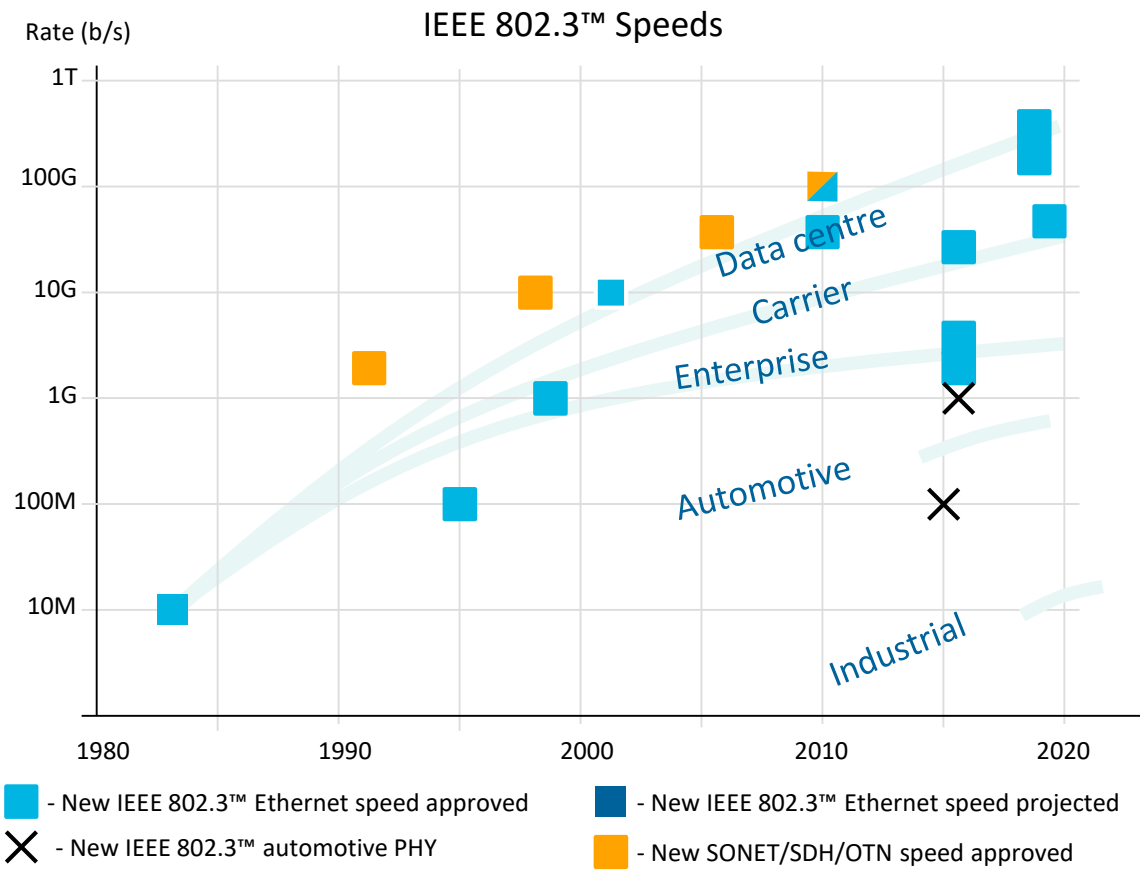
IEEE 802.11ah™(Sub 1 GHz) + IEEE 802.11ba™
900 MHz Indoor IoT PANs
Wearables, sensors, smart home

PHY PROJECT SEQUENCE™



IEEE 802.3™ SPEEDS AND APPLICATION AREAS

First Six Speeds Took 27 Years, Next Six Took 5 Years



IEEE 802.1™ TIME-SENSITIVE NETWORKING

Time-Sensitive Networking (TSN) components

Time Synchronisation

IEEE 802.1AS-2011™ Timing and Synchronization
Includes a profile of IEEE 1588™ Precision
Clock Synchronization Protocol
IEEE P802.1AS™ Timing and Synchronization revision

Ultra reliability

IEEE 802.1CB-2017™ Frame Replication and Elimination
IEEE 802.1Qca-2015™ Path Control and Reservation
IEEE 802.1Qci™ Per-Stream Filtering and Policing
IEEE P802.1AS™ Timing and Synchronization revision

Synchronisation | **Reliability**

Latency | **Resource Management**

Bounded low latency

IEEE 802.1Qav-2009™ Credit Based Shaper
IEEE 802.3br-2016™ Interspersing Express Traffic
IEEE 802.1Qbu-2016™ Frame Preemption
IEEE 802.1Qbv-2015™ Scheduled Traffic
IEEE 802.1Qch-2017™ Cyclic Queuing and Forwarding
IEEE P802.1Qcr™ Asynchronous Traffic Shaping
IEEE 802.1DC™ Quality of Service Provision

Dedicated resources and API

IEEE 802.1Qat-2010™ Stream Reservation Protocol
IEEE 802.1Qcc-2018™ TSN configuration (P802.1Qcc)
IEEE P802.1CS™ Link-local Registration Protocol
IEEE P802.1Qdd™ Resource Allocation Protocol
IEEE P802.1CBdb™ Extended Stream Identification
IEEE 802.1Qcp-2018™, IEEE P802.1Qcx™, IEEE P802.1ABcu™,
IEEE P802.1Qcw™ and IEEE P802.1CBcv™ YANG Data Models

Introduction to IEEE 802.1™: Focus on the Time-Sensitive Networking Task Group
http://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-overview-1118-v01.pdf

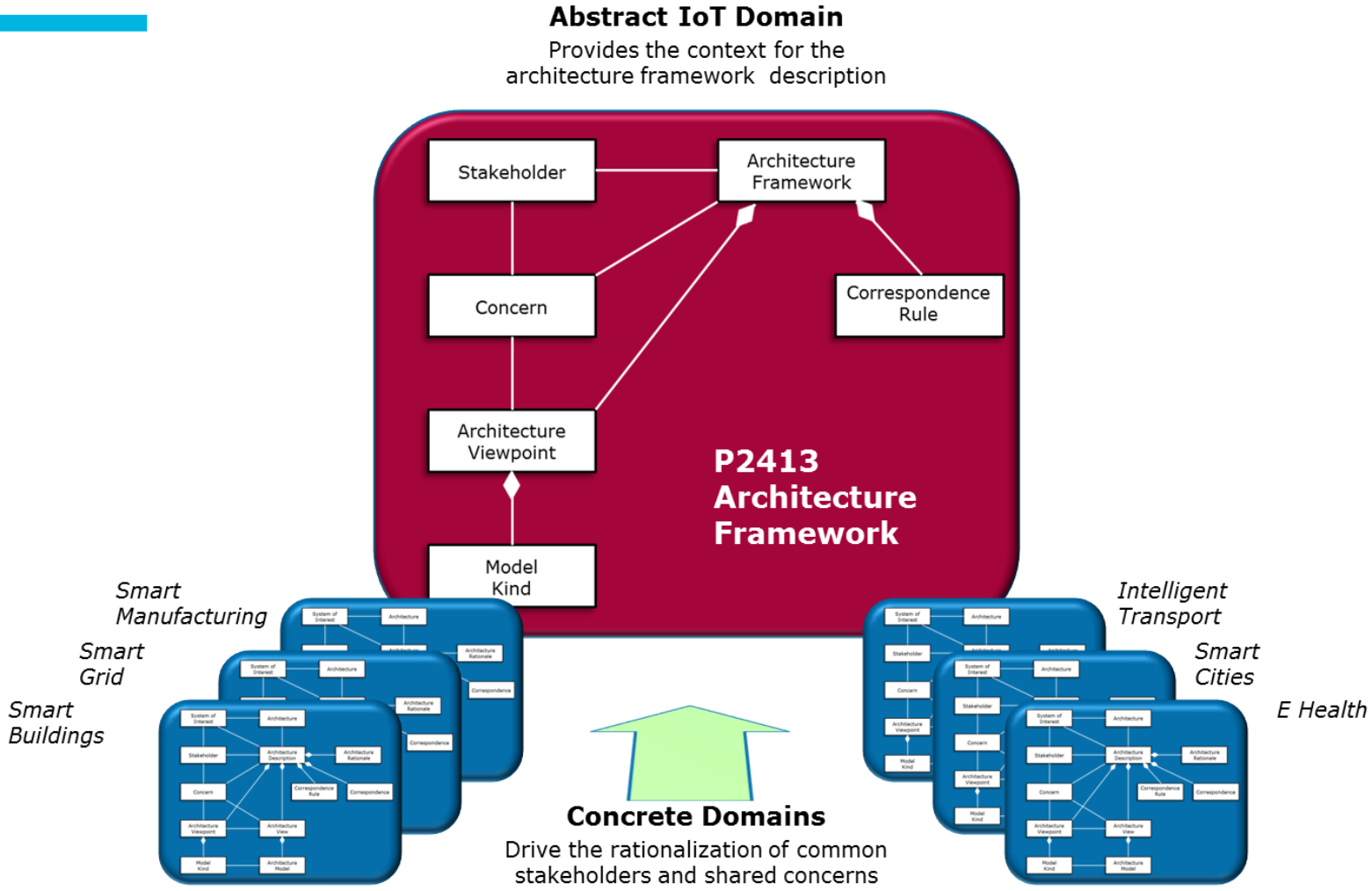
IEEE IoT SYSTEM AND APPLICATION LEVEL STANDARDS

IEEE 2413-2019™

Standard for an Architectural Framework for the Internet of Things (IoT)

- Promotes cross-domain interaction
- Descriptions of various IoT domains, definitions of IoT domain abstractions, and identification of commonalities between different IoT domains
- Quality "quadruple" that includes protection, security, privacy, and safety
- **Motivated by the need** to promote cross-domain interaction, aid system interoperability and functional compatibility, and further fuel the growth of the IoT market
- **Aims to provide** an architecture framework which captures the commonalities across different domains and provides a basis for instantiation of concrete IoT architectures

IEEE P2413™ Architecture Framework



IEEE 1451™ IoT HARMONIZATION

XMPP – (XSF, IETF, W3C, ISO, IEC, IEEE)

- eXtensible Messaging and Presence Protocol

MQTT – (OASIS)

- Message Queuing Telemetry Transport

REST – (W3C)

- Representational State Transfer

CoAP – (IETF)

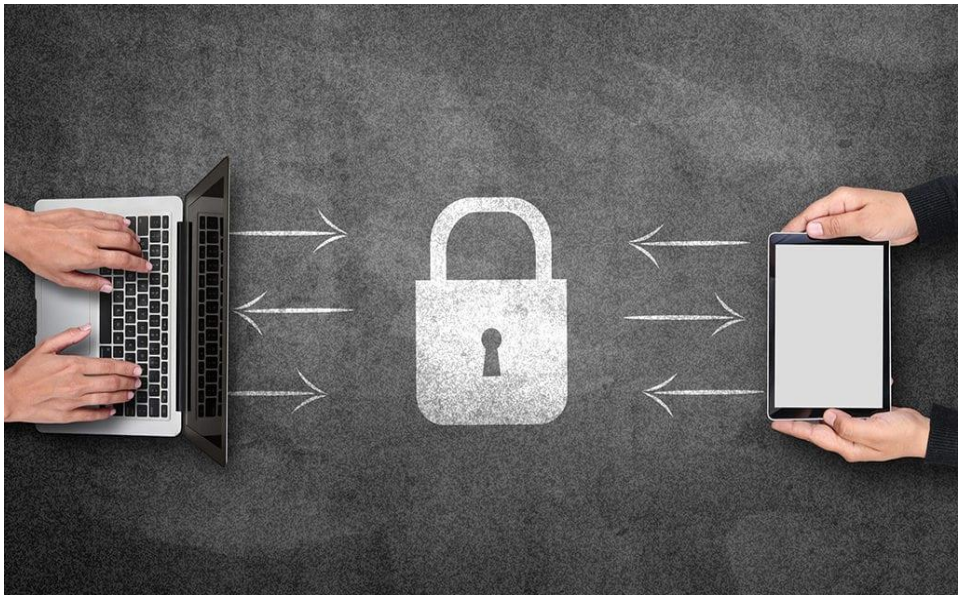
- Constrained Application Protocol

Legacy (IEC)

William J. Miller, mact-usa@att.net

IoT DATA SHARING

- The XMPP Architectural Framework facilitates sharing resources (i.e. sensors, actuators, data, audio, and/or video)
- Cyber-attacks are minimized by XMPP metadata isolation which includes encryption, device provisioning, and use of service brokers.
- Sensor data is only available between trusted end points and the data is not retained on a central server.



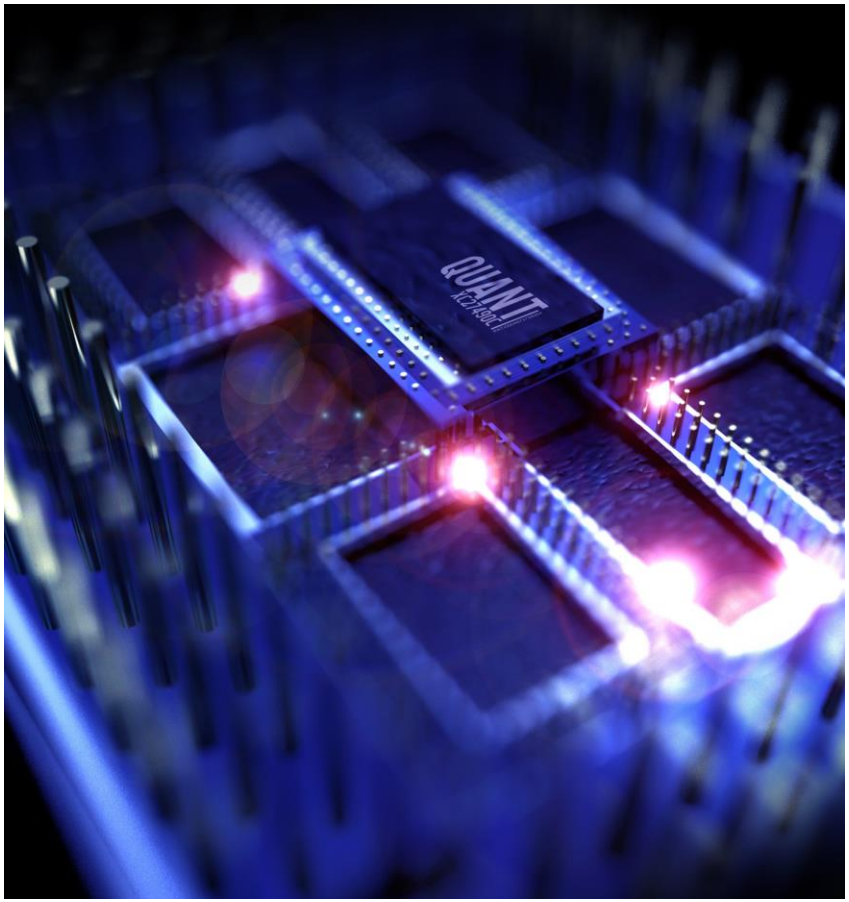
IEEE P1451-99™

Standard for Harmonization of Internet of Things (IoT) Devices and Systems

- Define a metadata bridge to facilitate IoT protocol transport for sensors, actuators, and devices.
- The standard addresses issues of security, scalability, and interoperability. This standard can provide significant cost savings and reduce complexity, and offer a data sharing approach leveraging current instrumentation and devices used in industry
- The backend of such a globally scalable, secure and interoperable network would be based on the eXtensible Messaging and Presence Protocol (XMPP),
- Key components and needs of a successful Smart City infrastructure will be identified and addressed. This standard does not develop Application Programming Interfaces (APIs) for existing IoT or legacy protocols.

IEEE P1931.1™

Standard for an Architectural Framework for Real-time Onsite Operations Facilitation (ROOF) for the Internet of Things (IoT)



- Technical and functional interoperability for IoT systems that operate and co-operate in a secure and independent manner within the context of a local environment such as home, factory, office or airport, etc.
- Defines an architectural framework, protocols and Application Programming Interfaces (APIs) for providing Real-time Onsite Operations Facilitation (ROOF).
- ROOF computing and networking for the data and the devices include next-hop connectivity for the devices, real-time context building and decision triggers, efficient backhaul connectivity to the cloud, and security & privacy.
- Defines how an end user is able to securely provision, and (de)commission devices.

IEEE P2733™

Standard for Clinical Internet of Things (IoT) Data and Device Interoperability with TIPPSS

- This standard establishes the framework with TIPPSS principles (Trust, Identity, Privacy, Protection, Safety, Security) for Clinical Internet of Things (IoT) data and device validation and interoperability.
- This includes wearable clinical IoT and interoperability with healthcare systems including Electronic Health Records (EHR), Electronic Medical Records (EMR), other clinical IoT devices, in hospital devices, and future devices and connected healthcare systems.
- This standard graduated from a pre-standards activity where a white paper was published: https://standards.ieee.org/standard/WhitePaper_10108.html

BLOCKCHAIN: AN IoT SECURITY PROTOCOL

Build Trust, Accelerate Transactions, Maintain Regulatory Compliance

- Track billions of devices
- Enable process of transactions and coordination between devices
- Decentralization eliminates single points of failure
- Cryptographic algorithms would make patient data more private
- The ledger is tamper-proof and cannot be altered by hackers as it does not exist in any one location
- Maintain a duly decentralized, trusted ledger of all transactions occurring in a network. This capability is essential to enable the many compliance and regulatory requirements

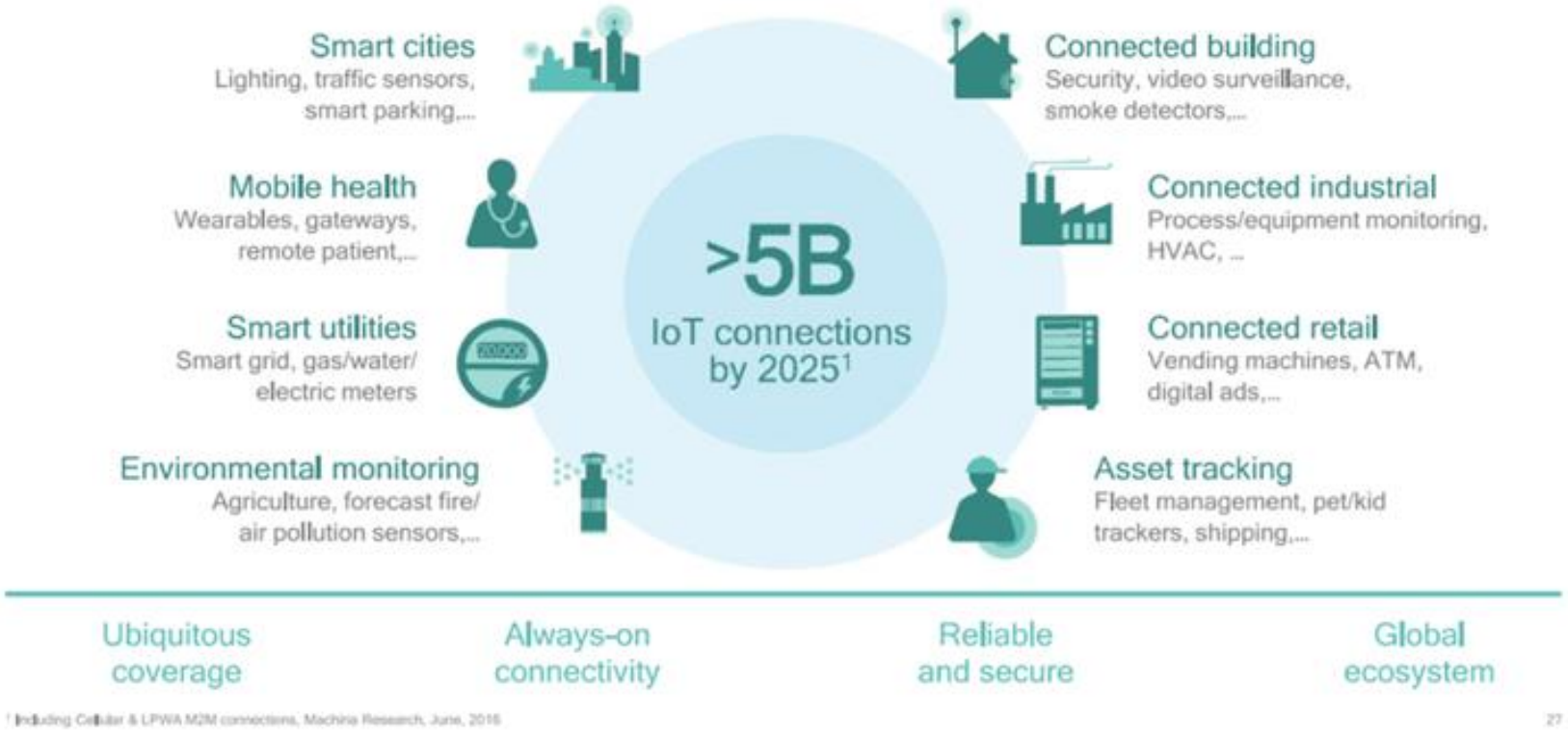
IEEE P2418.1™

Standard for the Framework of Blockchain Use in Internet of Things (IoT)

- Purpose of this project is to develop definitions, protocol, communication etc. for blockchain implementation within IoT architectural framework.
- The standard provides a common framework for blockchain usage, implementation, and interaction with the Internet of Things (IoT). The framework addresses items such as scalability, security and privacy challenges with regards to Blockchain in IoT.
- The use of blockchain technology for IoT enables decentralized, autonomous communication (peer-to-peer, consumer-to-machine, machine-to-machine) without the need for a trusted intermediary.

SENSORS AND IoT

Wireless Technologies Enable a Wide Range of IoT Services



Qualcomm Technologies, Inc., June 2017;
https://www.slideshare.net/qualcommwirelessevolution/leading-the-lte-iot-evolution-to-connect-the-massive-internet-of-things

[1] Including cellular and low power, wide area M2M connections, Machine Research, May 2017

IEEE P2510™

Standard for Establishing Quality of Data Sensor Parameters in the Internet of Things Environment

- New Real Time Analytics need to know, not only the ‘data’, but also the ‘quality of the data that are receiving to proceed to "close O&G pipes, stop cars, send alerts, etc.’ ”.
- Every day is more common to have actuators with interaction with multiples IoT autonomous systems to take decisions in real time, e.g., speed, localization, temperature, and other information that should be correlated before the actuator take an action. This is critical because before taking decisions customers could understand the total probable percentage error for this decision.
- Parameters to understand the quality of the data is critical to improve the productivity in the business operation and enforce the industrial or homeland security in field operation environments.
- IEEE P2510™ has established the ”IEEE Conformity Assessment Program” for Sensor Qualification.

IEEE IoT STANDARDS

Focus	Description
IEEE LAN/MAN Standards (popularly known as IEEE 802™)	Ethernet, Bridging and Virtual Bridged LANs Wireless LAN, Wireless PAN, Wireless MAN, Wireless Coexistence, Media Independent Handover Services and Wireless RAN
IEEE 1451™	Family of standards for smart transducers and sensors. IEEE 1451-1-4™ is based on the XMPP protocol
IEEE P1451-99™	IoT Harmonization (under review to form WG)
IEEE 1775™	IEEE Standard for Power Line Communication Equipment--Electromagnetic Compatibility (EMC) Requirements
IEEE 1901.2™	IEEE Standard for Low-Frequency (less than 500 kHz) Narrowband Power Line Communications (Smart Grid applications)
IEEE 1903™	IEEE Standard for the Functional Architecture of Next Generation Service Overlay Networks
IEEE 1905.1™	IEEE Standard for a Convergent Digital Home Network for Heterogeneous Technologies
IEEE P1912™	Privacy and Security Architecture for Consumer Wireless Devices Working Group

To learn more, visit us at: standards.ieee.org/innovate/iot

IEEE IoT STANDARDS

Focus	Description
IEEE P1930.1™	Recommended Practice for Software Defined Networking (SDN) based Middleware for Control and Management of Wireless Networks
IEEE 1931.1™	ROOF Computing: technical and functional interop for IoT systems that operate and co-operate in a secure and independent manner within the local context (Smart Cities)
IEEE 2030.5™	IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard
IEEE P2040™	Family of Transportation Standards
IEEE P2302™ & Intercloud Testbed	Development of a standard for intercloud interoperability and federation
IEEE 2410-2019™	Standard for Biometric Open Protocol
IEEE 2413™	IEEE Draft Standard for an Architectural Framework for the Internet of Things (IoT)
IEEE 2700™	IEEE Standard for Sensor Performance Parameter Definitions
IEEE 11073™	Address interoperability of personal health devices (PHDs)

To learn more, visit us at: standards.ieee.org/innovate/iot

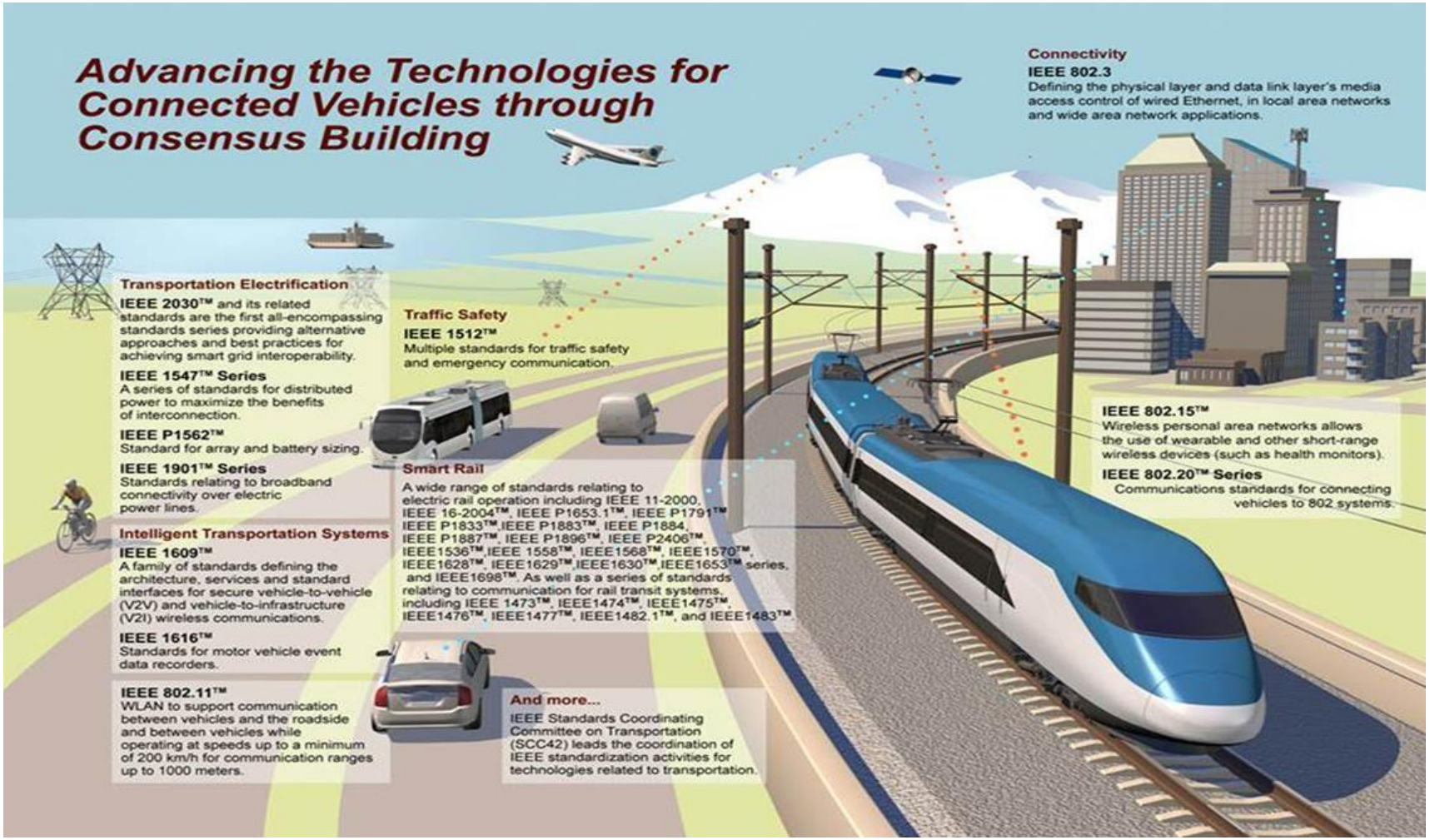
ACCELERATING THE IoT NETWORK EFFECT

Cooperation Amongst Global Standards Bodies and Consortia is Required to Enable Full IoT Commercialization & Innovation

IEEE SA IoT STANDARDS: DRIVING SMART CITY ECOSYSTEMS

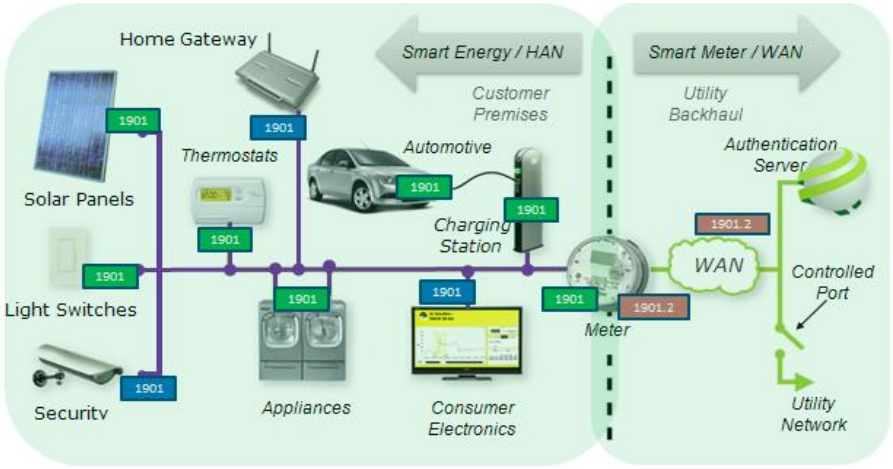
IEEE STANDARDS ON SMART CITIES

Transportation



IEEE STANDARDS ON SMART CITIES

Smart Grid and Digital Energy Management



- **IEEE 1547™ Series** on handling distributed resources in electric power systems
- **IEEE 1815™ Series** on electric power systems communications
- **IEEE 1901™ Series** Powerline Communication
- **IEEE 2030™ Series** on the smart grid, including electric vehicle infrastructure

Find more smart grid standards and projects at: http://smartgrid.ieee.org/standards

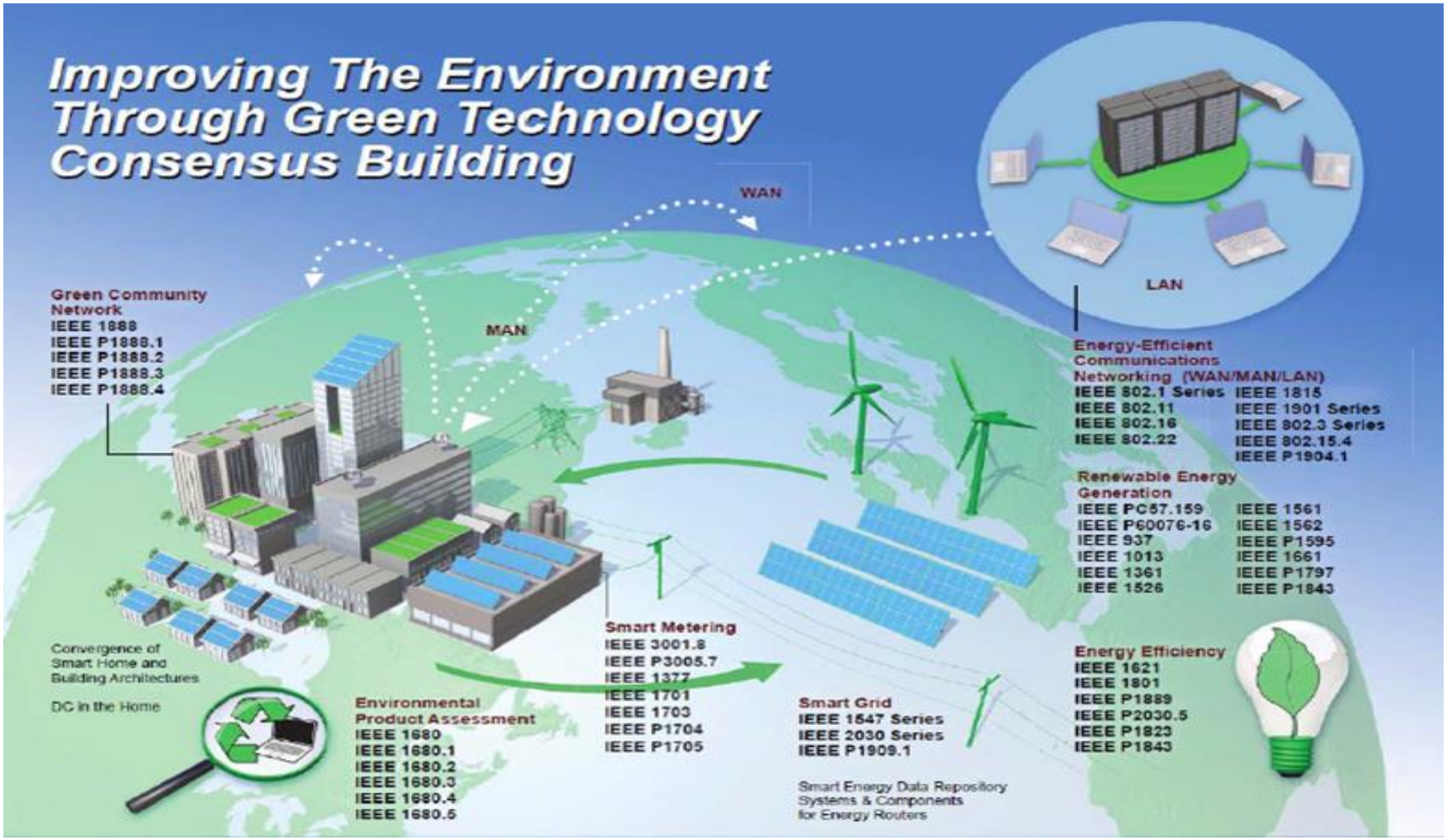
IEEE STANDARDS ON SMART CITIES

eHealth

- **IEEE 2410-2015™ - IEEE** Standard for Biometric Open Protocol
- **ISO/IEEE 11073™ Series** Health Informatics – Medical / Health Device Communication Standards

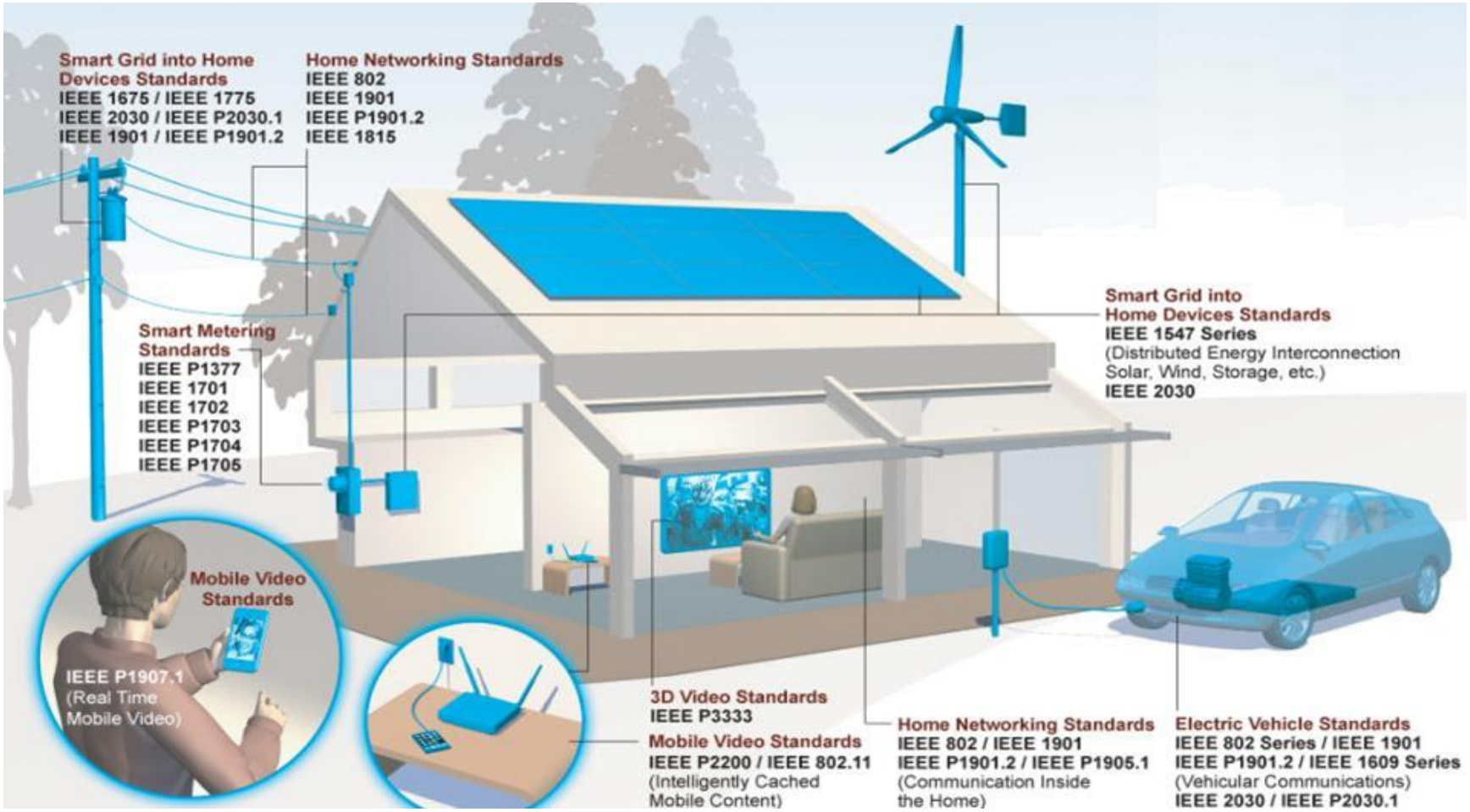
IEEE STANDARDS ON SMART CITIES

Green Technology



IEEE STANDARDS ON SMART CITIES

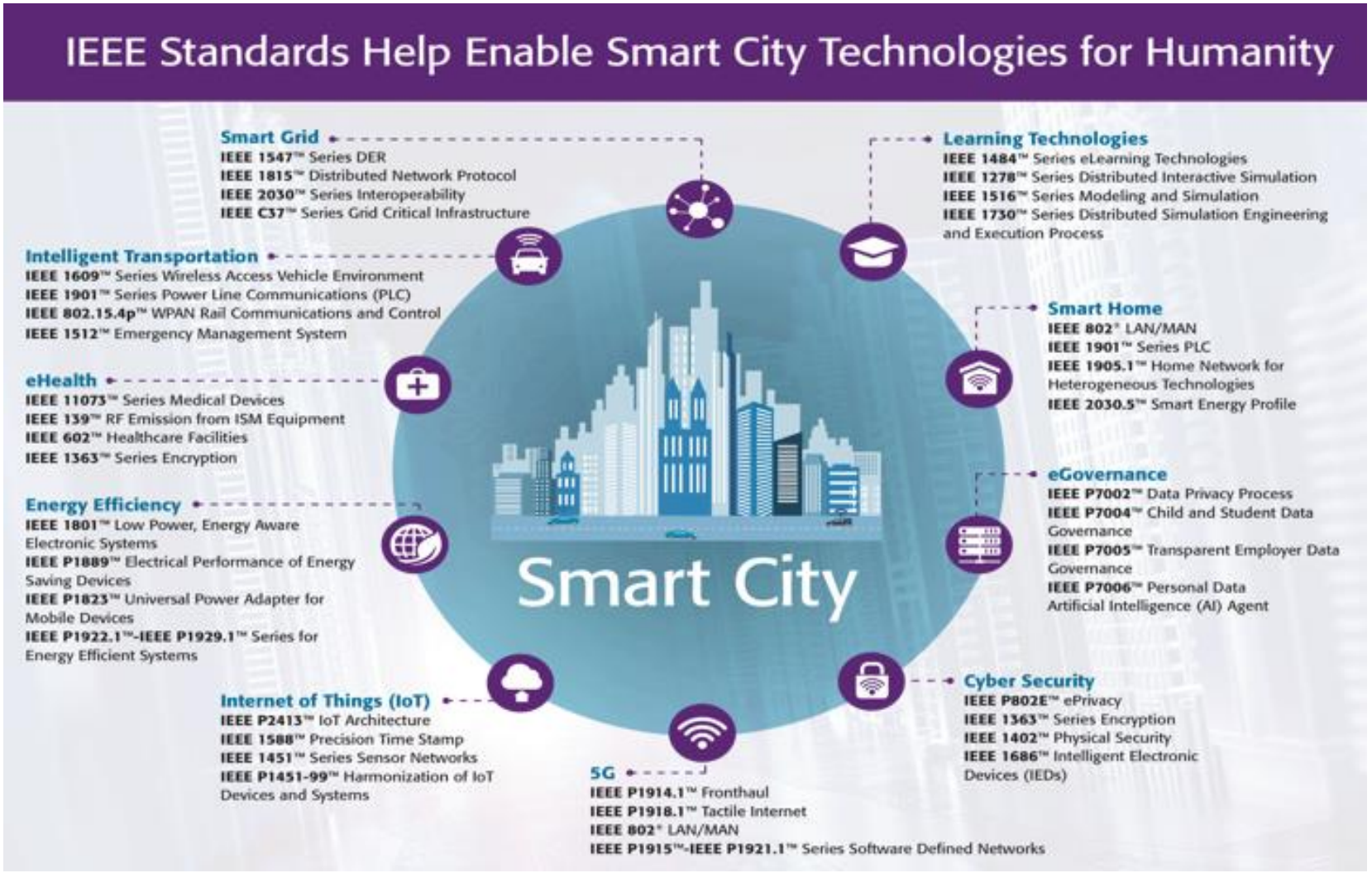
Smart Home



IEEE SA IS DRIVING PLATFORM CONVERGENCE FOR IoT

To learn more, visit us at: standards.ieee.org/innovate/iot

IEEE STANDARDS IMPACT SMART CITY TECHNOLOGY



THANK YOU

SRIKANTH CHANDRASEKARAN

Lead, IoT & Infrastructure Practice
IEEE Standards Association

sri.chandra@ieee.org