Nuts and Bolts (NaB) of the Internet of Things
IEEE 802 Plenary July 2014
San Diego, CA

Agenda – NaB IoT session July 2014

- Introduction
  - Chris DiMinico - Present agenda, background
- Agenda -
  - James Gilb gilb@ieee.org , Chair IEEE 802.24 TAG - Developments in 802.24
  - Paul Nikolich Chair 802 - Perspective/expectations of this effort, IoT in IEEE
  - Case studies:
    1. IoT – Sensors for Data Center Management – Mike Bennett – 3MG Consultancy
    2. Physical Security Market Overview – Andrew Jimenez – Anixter Inc.
  - Capabilities:
    1. Wireless Internet of Things – Fanny Mlinarski – octoScope, Inc
    2. Data Center Standards – Chris DiMinico – MC Communications
  - Discussion
    - Scope review
    - Next steps

IEEE 802

Background

•First meeting 802.24 IEEE 802 Plenary March 2014, Beijing, China

 −https://mentor.ieee.org/802.24/dcn/14/24-14-0008-00-0000-nuts-and-bolts-of-the-internet-of-things.pdf

Scope (proposed):

Forum to discuss substantive basis for applying 802 standards to evolving "IoT" application space and to gather together like minded experts interested in exploring the topic. In keeping with NaB approach the session is to focus on the application of 802 standards to ***connecting sensors (things)*** to the Internet "IoT".

Agenda – NaB IoT session March 2014

- Introduction
  - James Gilb gilb@ieee.org, Chair IEEE 802.24 TAG - restatement of meeting announcement
  - Chris DiMinico - Present agenda
- Agenda -
  - Paul Nikolich Chair 802 -(5 min) Paul's perspective/expectations of this effort
  - Hugh Barrass – Concept of IoT nuts and bolts – MIB - Common management
  - Case studies:
    1. Subsea Cabling/link Segments/testing (instrumentation standardization –Chris DiMinico http://www.siis-jip.com
       - Ethernet and Ecosystem
    2. Industrial automation/Broadcast –
       - Panduit - Bob Wagner, Rockwell Automation – Bob Lounsbury/Dayin Xu
    3. Automotive - Thomas Hogenmüller - Robert Bosch GmbH
  - Capabilities:
    1. PoE- PoDL (RTPGE) and 4-pair higher power - Dave Dwelley/ Koussalya Balasubramanian
    2. Channel characterization and testing – under Subsea case study
    3. Wireless –802.15, 802.11 - Bob Heile - Zigbee Alliance
- Next steps - Paul Nikolich

Paul Nikolich Chair 802 – Next Steps

- Developers and end-users of NaB IoT applications need a location where 802 standards and expert guidance on how these standards can be applied to solve their problems.

- We need a group that represents all that IEEE 802 has to offer regarding NaB of IoT such as:
  - Respond to enquiries
  - Develop white papers and application notes
  - Catalogue of NaB IoT standards
  - Direct deeper level questions/activities to the appropriate Working Groups.

- Now we need to identify the best way to continue the NaB of IoT discussion. Some options are--expand the scope of 802.24 to NaB IoT applications to act as a host regular cross-802 discussions on this topic.

- The group will meet on an ongoing basis to focus on the “nuts and bolts” of IoT i.e., understanding individual and developers IoT requirements.

- Chris DiMinico and Hugh Barrass volunteered to co-chair this effort under 802.24.
  - 2 hour meeting during Plenary sessions (more if necessary)
  - Teleconference calls

IoT – Sensors for Data Center Management

Mike Bennett - 3MG Consultancy
mjbennett@ieee.org

Topics

- Relationship of sensors and IoT
- Data Center Management (DCM) at LBNL
  - Extending the life of a legacy data center
- Data Center sensor network trend
- IEEE 802 work and the IoT
- Conclusion

Relationship of sensors and IoT

- IoT isn't a new concept
  - *In a few decades time, computers will be interwoven into almost every industrial product* - Karl Steinbuch, German computer science pioneer, 1966
- "Smart" objects play a key role in the Internet of Things vision[1]
  - Using sensors, they are able to perceive their context, and via built-in networking capabilities <u>they would be able to communicate with each other</u>, access Internet services and interact with people
- The *Things* in this talk are sensors used for Data Center Management

1. Friedemann Mattern and Christian Floerkemeier. 2010. *From the internet of computers to the internet of things*. In From active data management to event-based systems and more, Kai Sachs, Ilia Petrov, and Pablo Guerrero (Eds.). Springer-Verlag, Berlin, Heidelberg 242-259.

Data Center Management at LBNL:

Extending the Life of a Legacy Data Center

- In 2007 the IT Division began to work on a data center efficiency project[1]
- The data center:
  - Many years old
  - Approximately 5000 square feet
  - Raised floor
  - Approximately ½ MW power consumption
  - Cooled air forced under the floor and supplemented by overhead chiller system

1. Gregory Bell. 2008. *Towards a Greener Data Center: Tools & Techniques*. Presented at UCCSC 2008, UC Santa Barbara.

Data Center Management at LBNL

- Why bother with this old Data Center?
- Space is the final frontier at the Lab!
  - Limited for a number of reasons
    - Building ages range from many decades old to new
    - Challenging to get adequate power, cooling
    - Expensive to convert space to data center
- This old Data Center served two purposes
  - Space for clusters used for scientific computing
  - Space for servers supporting business systems
- Running out of power
  - Nowhere to move at the time

Data Center Management at LBNL

- IT and Energy Experts got together to work on the problem
  - Measured, Analyzed and documented major systems in the data center
  - Performed Computational Fluid Dynamics analysis
  - Determined efficiency – established a reference point
- The assessment revealed:
  - Data Center was being over-cooled
  - Humidifying and Dehumidifying simultaneously
  - Lots of perforated floor tiles
  - Lots of panel blanks missing
  - Ineffective air-flows

Data Center Management at LBNL

- Improvements:
  - Several steps taken to improve air-flow:
    - Install panel blanks and curtains
    - Adjust the number and placement of perforated floor tiles
    - Converted the overhead plenum to hot-air return
    - Redirected the supplementary cooling to under-floor
  - Visualization of air-flow
  - Water cooling
- Deployed a wireless sensor system to measure and monitor efficacy of changes

Data Center Management at LBNL

- Wireless sensor system measured
  - Temperature
  - Pressure under the raised floor
  - Current
  - Humidity
- 200 monitors installed
  - Wireless sensors used 802.15.4; self-organizing
- System provided historical and real-time plots, enabling IT Data Center staff to see the impact of changes such as maintenance, system failures, etc.

Data Center Management at LBNL

- What was the outcome?
  - Increased IT load by more than 50% [1]
    - No increase in infrastructure energy use
    - Shut down unnecessary cooling systems

- This is just one small example, but the benefits are obvious.
- The techniques and tools referenced here have become best-practices and included in specifications
- How does this affect the trend of sensor deployment in Data Centers?

1. David Edgar and Ray Pfeifer. 2011. *Power Management in a Legacy Data Center*. UptimeInstitute Symposium, Santa Clara, CA.

Data Center Sensor Network Trend

- Project Genome[1]
  - The overarching goal of the project is to understand how energy is consumed in data centers as a function of:
    - facility design, cooling supply, server hardware, and workload distribution through data collection and analysis
  - use this understanding to optimize and control data center resources

1. *The Architecture Journal, http://msdn.microsoft.com/en-us/library/dd393313.aspx, January, 2009*

IEEE 802

Data Center Sensor Network Trend

- Project Genome[1]
  - Also indicated reason for data center inefficiency was due to “lack of visibility in the data center operating conditions”
  - The Microsoft team saw wireless sensor network technology as “an ideal candidate for the monitoring task”
  - ~700 sensors deployed in a multi-mega-watt data center.
    - Developed their own “genomotes” using 802.15.4 for low-cost, low-power operation
  - In 2009 it was one of the largest sensor networks in production use.
  - Showed that wireless sensor networks (RACNet) can maintain high data yield:
    - Provided over 99 percent data reliability, with 90 percent of the data being collected under the current soft real-time requirement of 30 seconds.

1.The Architecture Journal, http://msdn.microsoft.com/en-us/library/dd393313.aspx, January, 2009

Data Center Sensor Network Trend

- The same vendor used by the LBNL Data Center published 5 case studies[1]:
  - Sensors deployed in nearly 300,000 sq. ft. of various Data Center space
  - 14,235 sensors
- More recently, 802.15.4/ZigBee devices expected to play a dominant role in the fixed Wireless Sensor Network (WSN) market
  - Annual shipments forecast to reach 1 Billion by 2019[2]
- WSNs aren't the only driver for the IoT
  - What other IEEE 802 standards are driving the IoT?

1.www.synapsense.com
2.802.15.4 & ZigBee: Enabling the Internet of Things, A Market Dynamics report (10th edition), Q1, 2014

IEEE 802 work and the IoT

IEEE 802 Standard/Project/SG	Technology	Supporting the IoT?
P802.3bp	1-pair 1GbE; Automotive/Industrial	Yes
P802.3bu	1-pair Power over Data Lines	Yes
GigE over POF SG	1 GbE over Plastic Optical Fiber	Yes
1 Twisted Pair 100 Mb/s Ethernet SG	1-pair 100 MbE; Automotive/Industrial	Yes
P802.3af	DTE Power via MDI (PoE)	Yes
802.3at	DTE Power Enhancements (PoE enhanced)	Yes
802.11	Wireless Local Area Networks	Yes
802.15	Wireless Personal Area Networks	Yes
802.24	Smart Grid Technical Advisory Group (TAG)	Yes

- Not an exhaustive list – more work to do …

Conclusion

- Environmental sensors in Data Centers are essential to maintaining efficient operation
- The life of a legacy data center was extended by
  - Conducting an analysis of the data center systems
  - Documenting these systems and calculating the efficiency of the data center
    - Establish the reference
  - Making improvements
  - Continually measuring and monitoring the environment
    - This was done with a wireless sensor system
- The techniques used in this Data Center have become best-practices in Data Center Management

Conclusion

- Data Center Management is one use-case for the Internet of Things
- Given the numbers and sizes of Data Centers, DCM will contribute to the growth of the IoT
- Open question:
  - Are there use-cases that could benefit through standardization?
- Still need more information
  - Many other DCM use-cases
  - Many other use-cases
  - Please contribute!v

Physical Security Market Overview

Andy Jimenez – Anixter Inc.

IEEE P802.3 LMSC

San Diego, California USA

July, 2014

Introduction

- State of IP-Based Physical Security Market
  - Video Surveillance
  - Electronic Access Control
- Areas to Develop

State of the Physical Security Industry

At the Crossroads

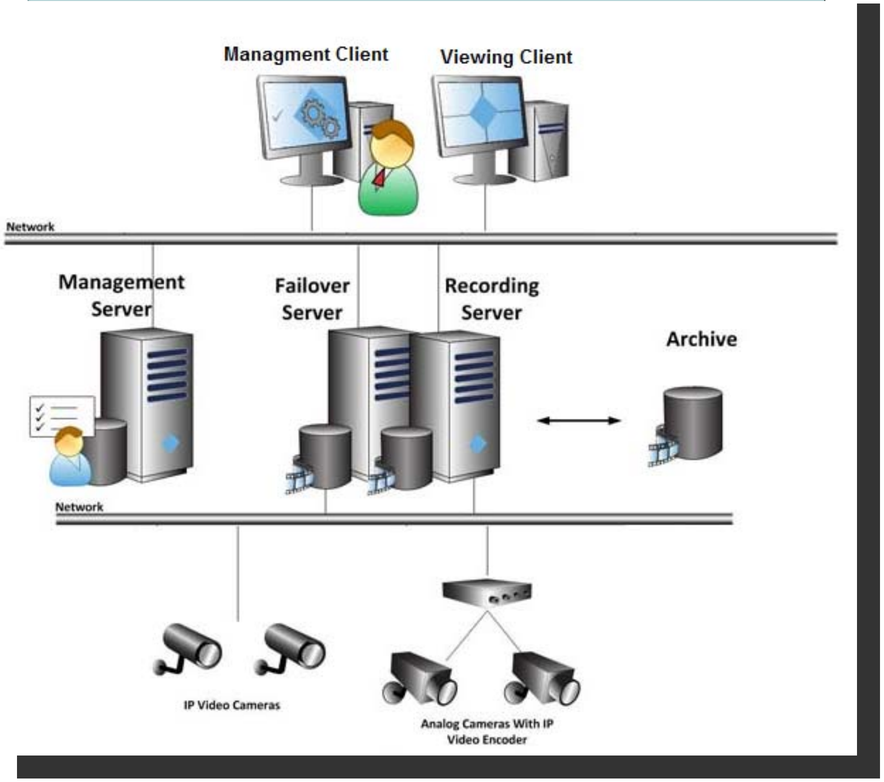
	Past	Present	Future
Standards	Limited	Developing	Established
Cable Infrastructure	Coax and Multiconductor	Coax, Multiconductor, UTP and Fiber	UTP, Fiber and Wireless
Product Selection	Single Manufacturer	Multimanufacturer	Fully Interoperable
Compatibility	None	Limited	Forward and Backward

Technical Trends

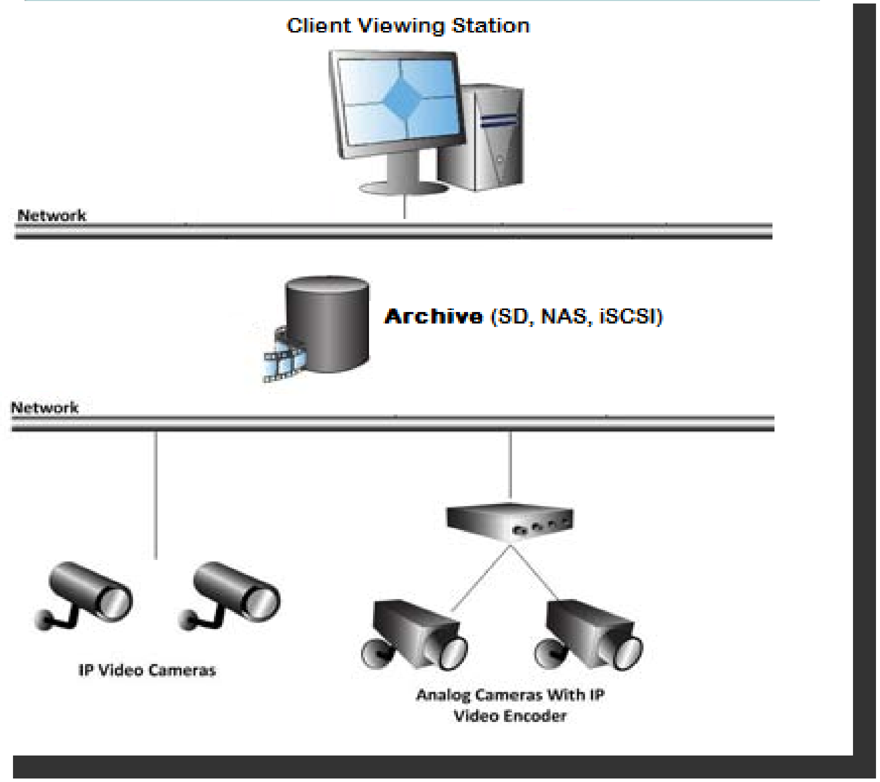
- According to IHS, by 2017:
  - More than 88.4% of all network camera shipments will be megapixel resolution
  - Over 92% are forecast to be HD compliant
- HD resolution (1920x1080) seen as “enough”
- Bandwidth and storage requirements
  - High Efficiency Video Coding (HEVC)
  - Bandwidth requirements being driven down with advancements in compression technology
  - Current IEEE 802.3, 802.11, and 802.16 standards sufficient for data transport
- Power requirements
  - Large percentage of fixed and PTZ cameras supported by 802.3af and 802.3at (<30 watts)
  - Outdoor cameras will take advantage of 4PPoE (30-50 watts)
    - Potential for higher power efficiencies

CENTRALIZED VS. DECENTRALIZED ARCHITECTURES

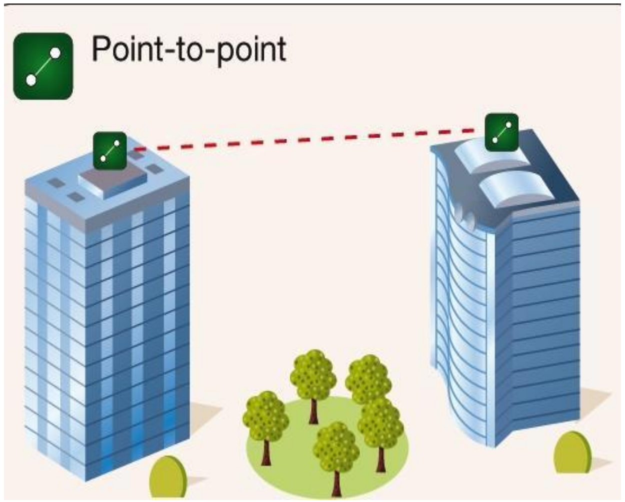
Centralized Architecture

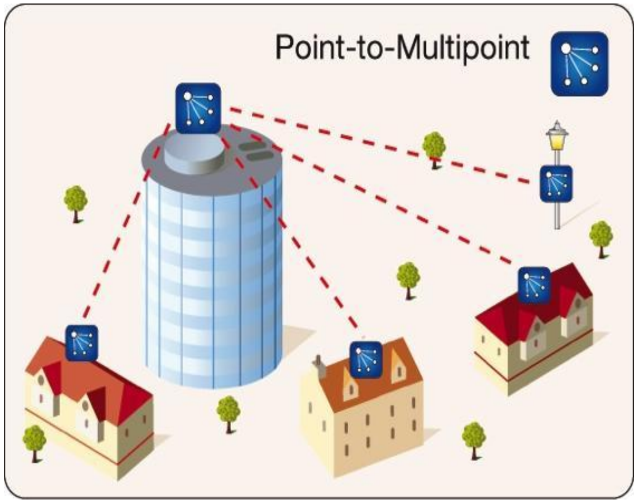


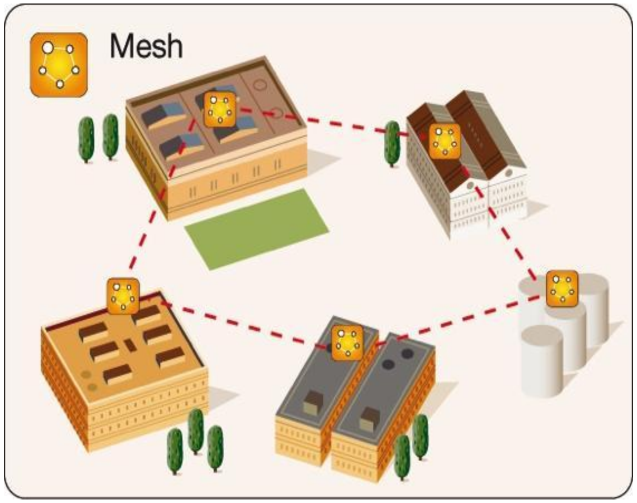
Decentralized Architecture

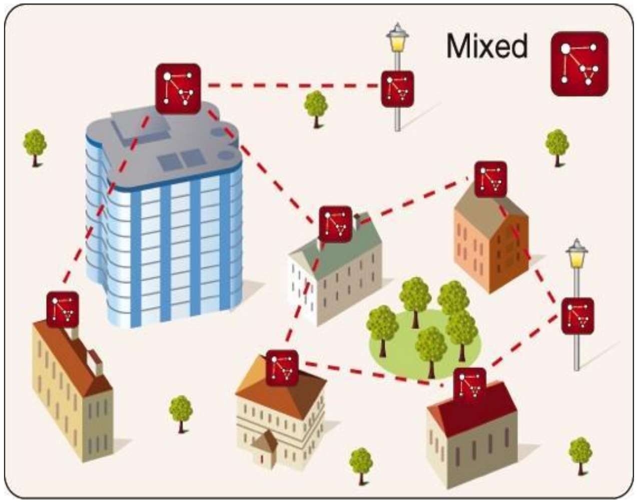


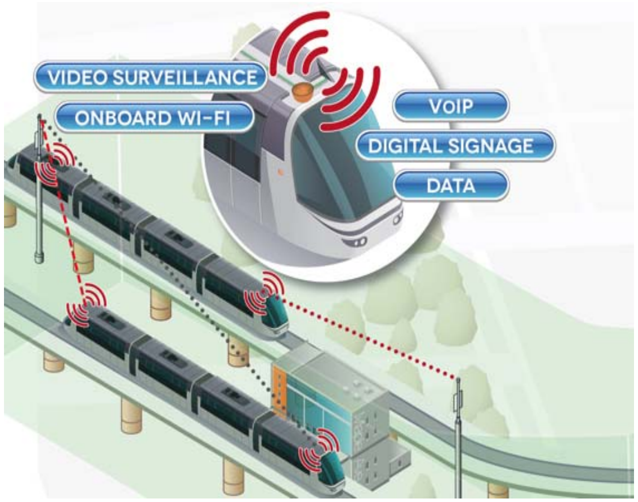
WIRELESS ARCHITECTURES











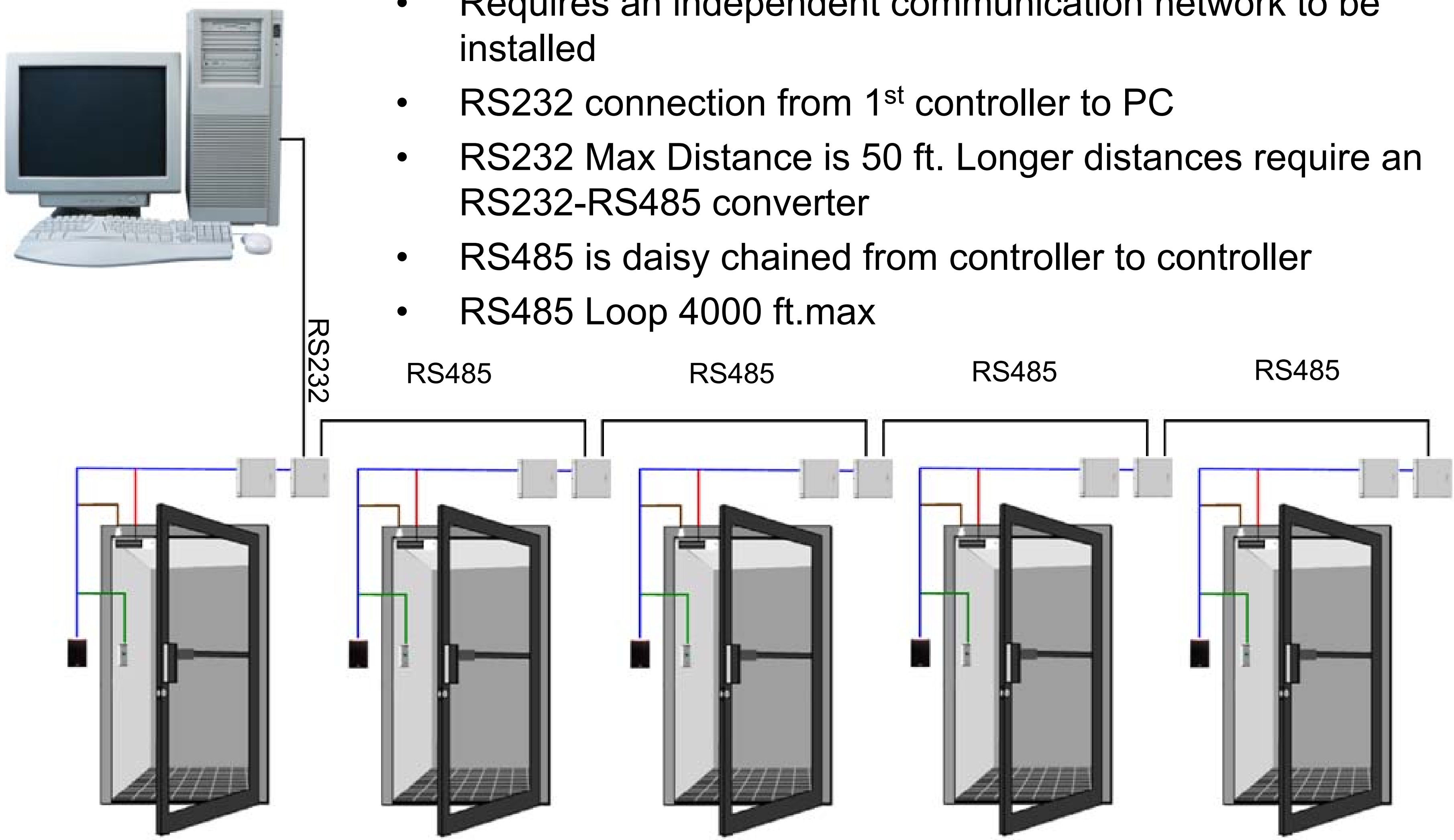
Source - Fluidmesh

Door Controller Types

- IP:
  - Connects to the PC host directly through a TCP/IP network.
  - IP controllers provide greater functionality than serial controllers and can be integrated directly into existing IT networks.
- Keypads:
  - Simple standalone controllers typically used to control access to single doors.
  - Operates up to three outputs and can be used to trigger a door strike, an electromagnetic door lock, or another relay-activated device.
- Serial:
  - Connects to the PC host through an RS-485 serial connection or similar serial transmission.
- Edge devices:
  - Intelligent IP readers that usually do not have traditional control panels; they communicate with the PC that acts as a host.

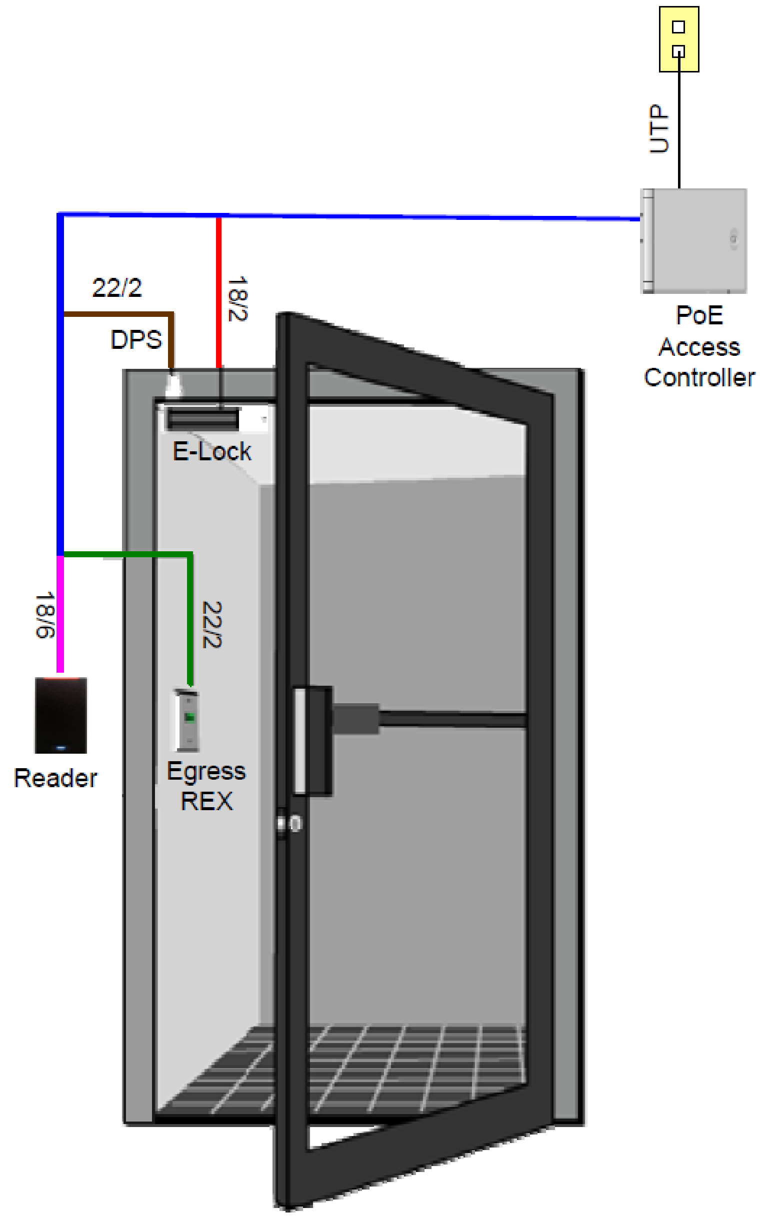
Analog Access Control

- Dedicated PC is required to host software and manage the access control system
- Requires an independent communication network to be installed
- RS232 connection from 1st controller to PC
- RS232 Max Distance is 50 ft. Longer distances require an RS232-RS485 converter
- RS485 is daisy chained from controller to controller
- RS485 Loop 4000 ft.max



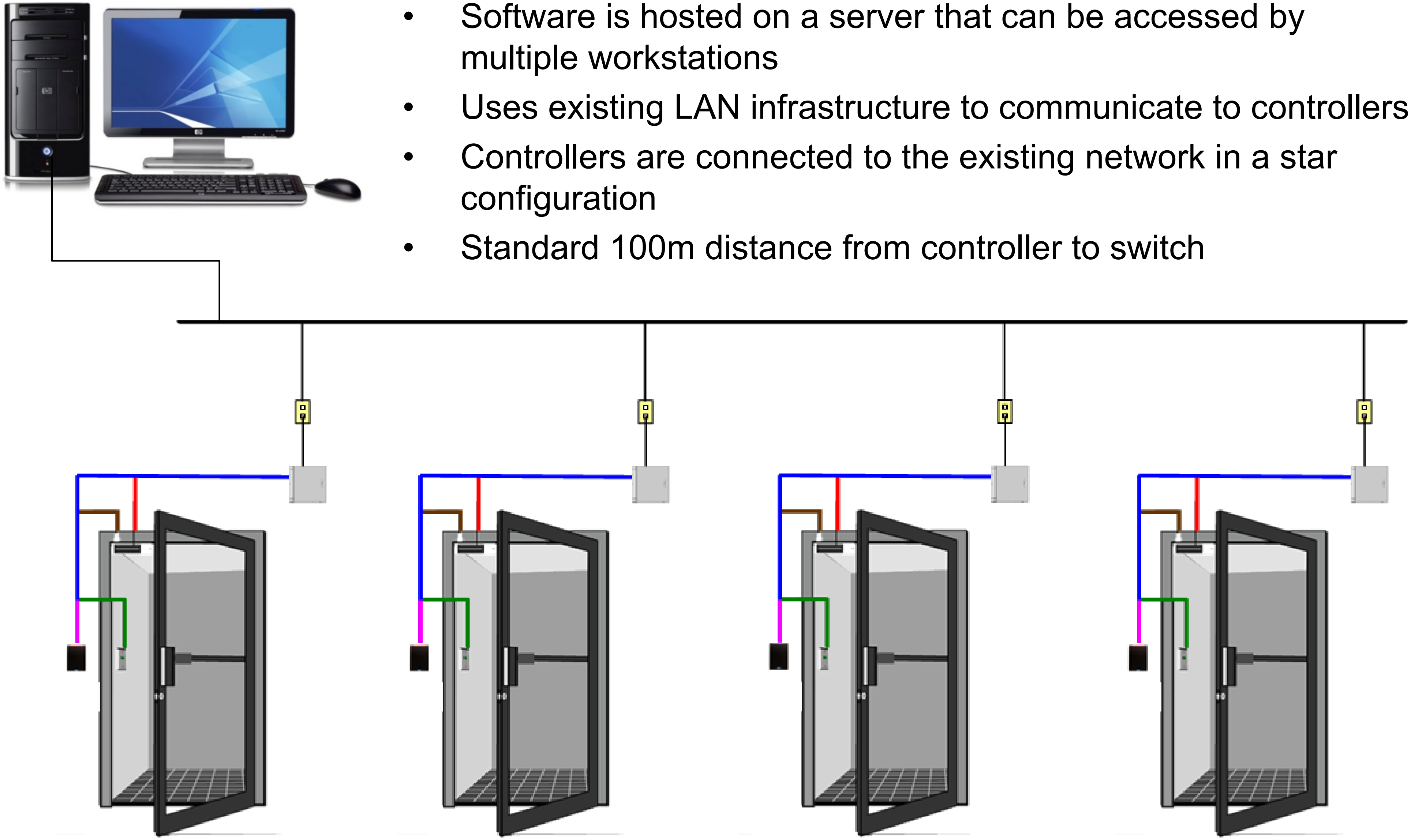
IP Access Control

- Power is provided by a PoE switch or midspan power
- Back up power is provided by an UPS
- Each controller is IP addressed
- Serial connections from the door to the controller is standard low voltage cabling
- IP-Based communication cabling is TIA/ISO standard balanced twisted-pair



IP Access Control

- Software is hosted on a server that can be accessed by multiple workstations
- Uses existing LAN infrastructure to communicate to controllers
- Controllers are connected to the existing network in a star configuration
- Standard 100m distance from controller to switch



Technical Trends

- Bandwidth and storage requirements
  - Low bit-rate systems (<1Mbps)
  - Current IEEE 802.3 and 802.11 standards sufficient for data transport
- Power requirements
  - EAC controller supported by 802.3af and 802.3at (<30 watts)
  - Components (e.g. door locking hardware, readers, request-to-exist) driven by controllers will take advantage of 4PPoE (30-50 watts)
    - Potential for higher power efficiencies

Organizations Driving Standardization

- Security Industry Association (SIA)
  - Open Systems Integration and Performance Standards (OSIPS)
  - Access control and digital video interface
  - ANSI accredited
- Physical Security Interoperability Alliance (PSIA)
  - Manufacturers: 80+
  - Products: 100+
  - Working groups: IP video, video analytics, recording and content management, access control and systems
- Open Network Video Interface Forum (ONVIF)
  - Manufacturers: 310+
  - Products: 915+
  - Working groups: network video and physical access control

IEEE 802

Organizations Driving Standardization

- Open Network Video Interface Forum (ONVIF) **cont'd**
  - To facilitate the development of a global open standard
  - Standardize communication between IP-based physical security devices
  - Ensure interoperability
  - Open to all companies

Summary

- Opportunities exist to develop new IoT technologies for physical security market
- Video surveillance applications well supported with current IEEE 802.3 and 802.11 standards
- EAC market still evolving
- Explore potential partnership opportunities with physical security standards and industry organizations

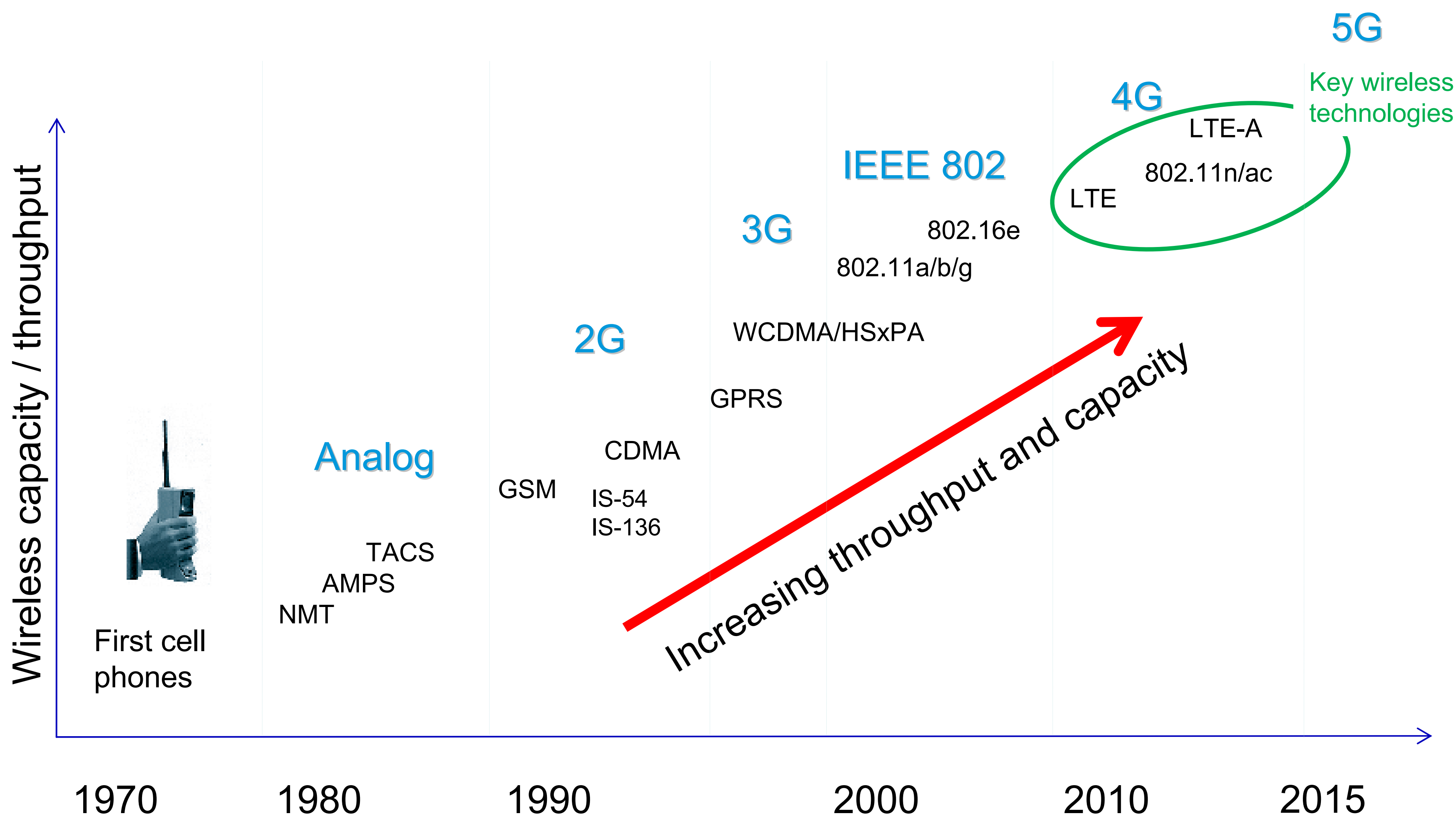
Wireless Internet of Things

Fanny Mlinarsky
octoScope, Inc.
fm@octoscope.com

What is the Role of Wireless in IoT?

- History of wireless standards
- Key new wireless technologies
- Application examples
  - Connected vehicle
  - Video distribution

Brief History of Wireless



G = generation

History of IEEE 802.11

- **1989**: FCC authorizes ISM bands
  - 900 MHz, 2.4 GHz
- **1990**: IEEE begins work on 802.11
- **1994**: 2.4 GHz products begin shipping
- **1997**: 802.11 standard approved
- **1998**: FCC authorizes UNII band
  - 5 GHz
- **1999**: 802.11a, b ratified
- **2003:** 802.11g ratified
- **2006:** 802.11n draft 2 certification by the Wi-Fi Alliance begins
- **2009:** 802.11n certification

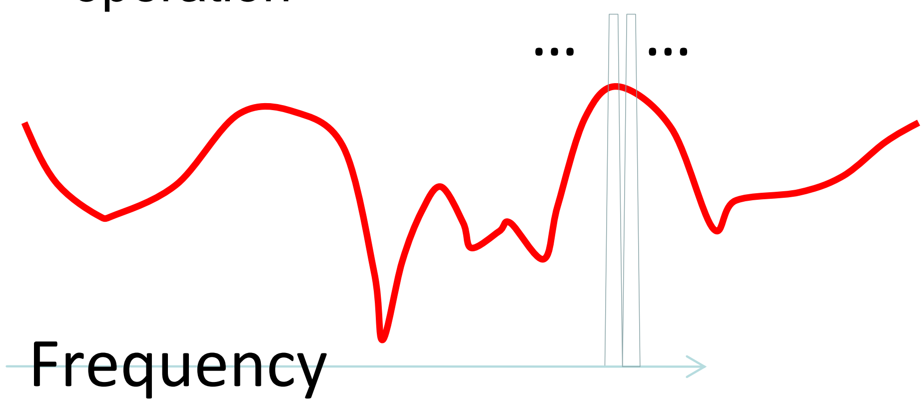
→ **2013:** 802.11ac (up to 6.9 Gbps) and 802.11ad (up to 6.8 Gbps)

802.11 has pioneered commercial deployment of OFDM and MIMO – key wireless signaling technologies

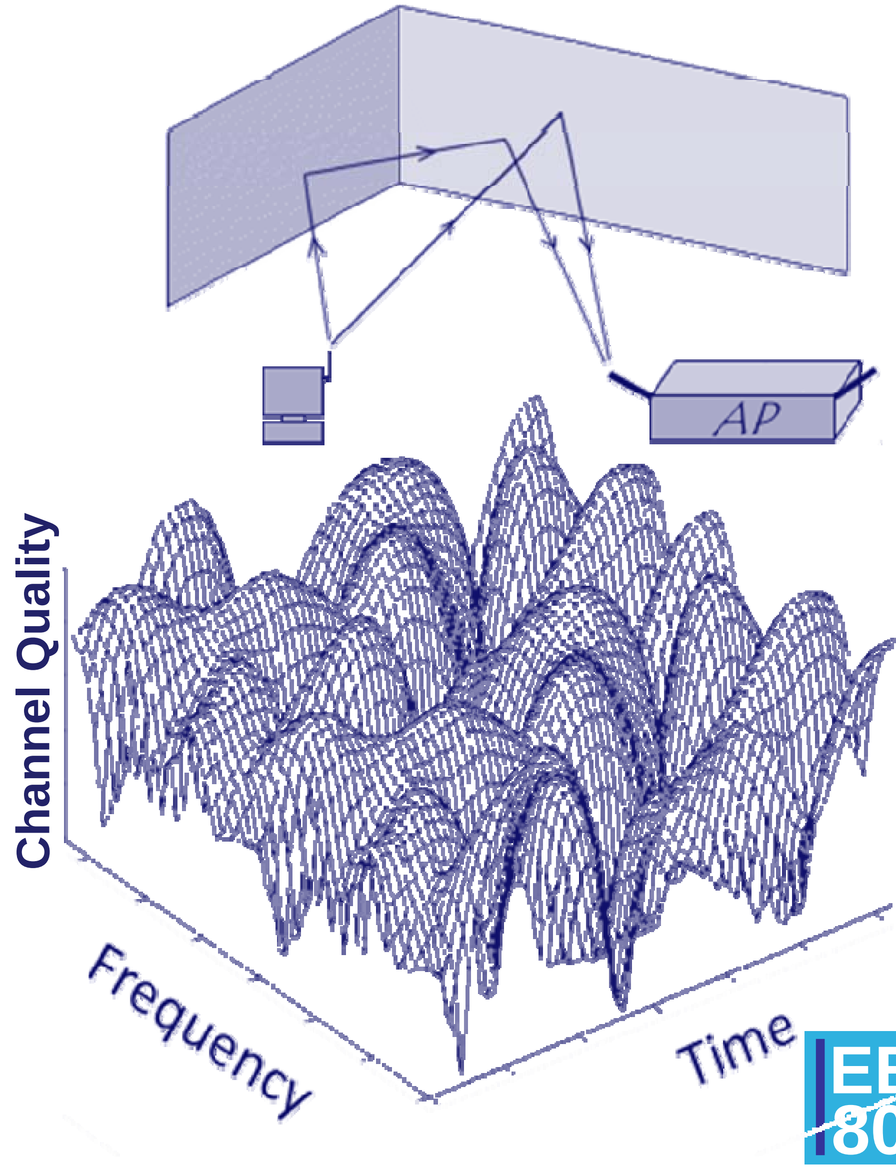
ISM = industrial, scientific and medical
UNII = Unlicensed National Information Infrastructure

Wireless Channel

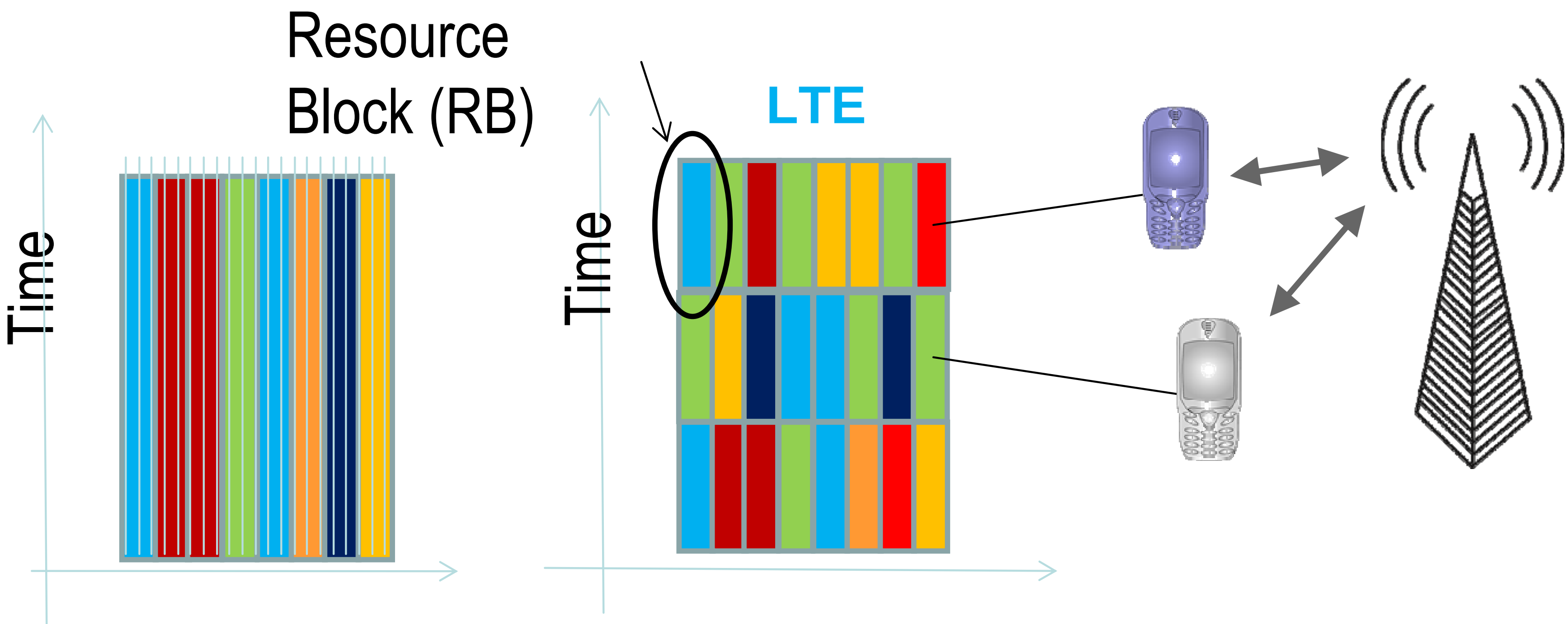
- Time and frequency variable
- OFDM transforms a frequency- and time-variable fading channel into parallel correlated flat-fading channels, enabling wide bandwidth operation



Frequency-variable channel appears flat over the narrow band of an OFDM subcarrier.



OFDMA



Frequency allocation per user is constant vs. time

Frequency per user is dynamically allocated vs. time slots

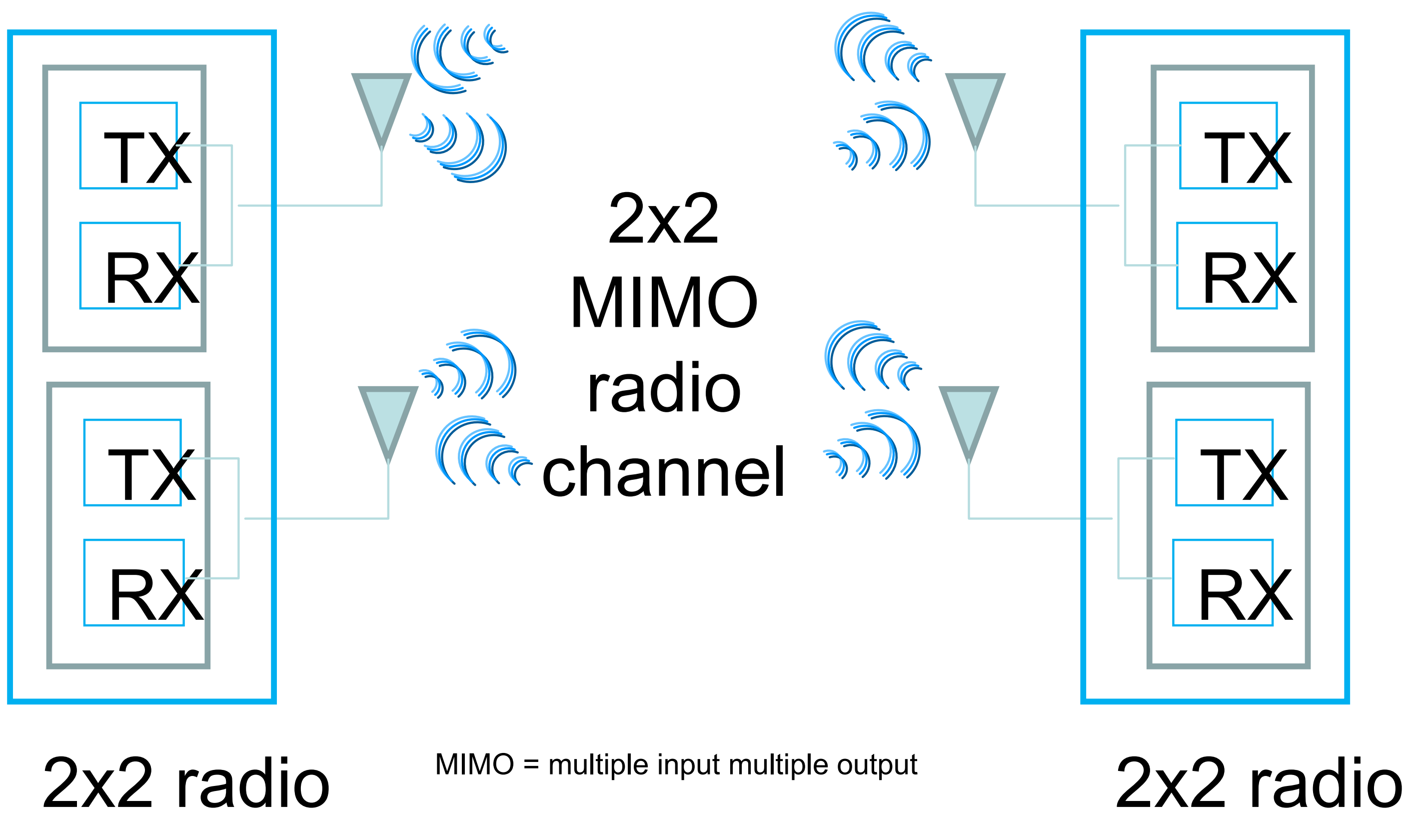
User 1 | User 2 | User 3 | User 4 | User 5

OFDM = orthogonal frequency division multiplexing
OFDMA = orthogonal frequency division multiple access

IEEE 802

MIMO Systems

MIMO systems are often described as NxM, where N is the number of transmitters and M is the number of receivers.



MIMO Modes of Transmission

MIMO Mode	Explanation
Spatial Multiplexing	Use of multiple MIMO radios to transmit two or more data streams in the same channel.
TX diversity	Use of multiple MIMO radios to transmit slightly different versions of the same signal in order to optimize reception of at least one of these versions. TX diversity schemes include space time block coding (STBC), space frequency block coding (SFBC) and cyclic delay diversity (CDD).
RX diversity	Use of multiple MIMO radios to combine multiple received versions of the same signal in order to minimize PER. A common RX diversity technique is maximal ratio combining (MRC).
Combination of TX and RX diversity	Use of TX diversity at the transmitting device in combination with RX diversity at the receiving device.
Beamforming	Use of multiple MIMO transmitters to create a focused beam, thereby extending the range of the link or enabling SM.
Multi-user MIMO (MU-MIMO)	Forming multiple focused beams or using TX diversity techniques to enable simultaneous communications with multiple device. Typically beamforming is done by a base station or an access point (AP) to communicate simultaneously with multiple client devices.

Adaptation Parameters 802.11a/b/g/n/ac

Adaptation	Variables
Modulation	BPSK, QPSK, 16-QAM, 65-QAM, 256-QAM
Signaling	CCK, DSSS, OFDM
Coding rate	1/2, 3/4, 5/6
# spatial streams	1 to 8
Channel width	Wi-Fi: 20/40/80/160 MHz LTE: up to 20 MHz
Guard Interval (GI)	Wi-Fi: 400/800 ns; LTE: 5.2 usec
MIMO mode	Spatial Multiplexing (SM) TX diversity RX diversity Beamforming

CCK = complementary code keying
DSSS = direct sequence spread spectrum
OFDM = orthogonal frequency division multiplexing
BPSK = binary phase shift keying
QPSK = quadrature phase shift keying
QAM = quadrature amplitude modulation

Refer to 802.11 documents [1-2] for details of the latest 802.11 technology and data rate computation [12]

DSRC Riding over 802.11p

Applications	Intersection Collision Warning	Pre-Crash Sensing	Do Not Pass Warning
	Electronic Brake Light Warning	Left Turn Across Path Warning	…
Protocol	IEEE 1609	ETSI TC-ITS	
Radio	IEEE 802.11p		

DSRC = direct short range communications

DSRC Radio Challenges

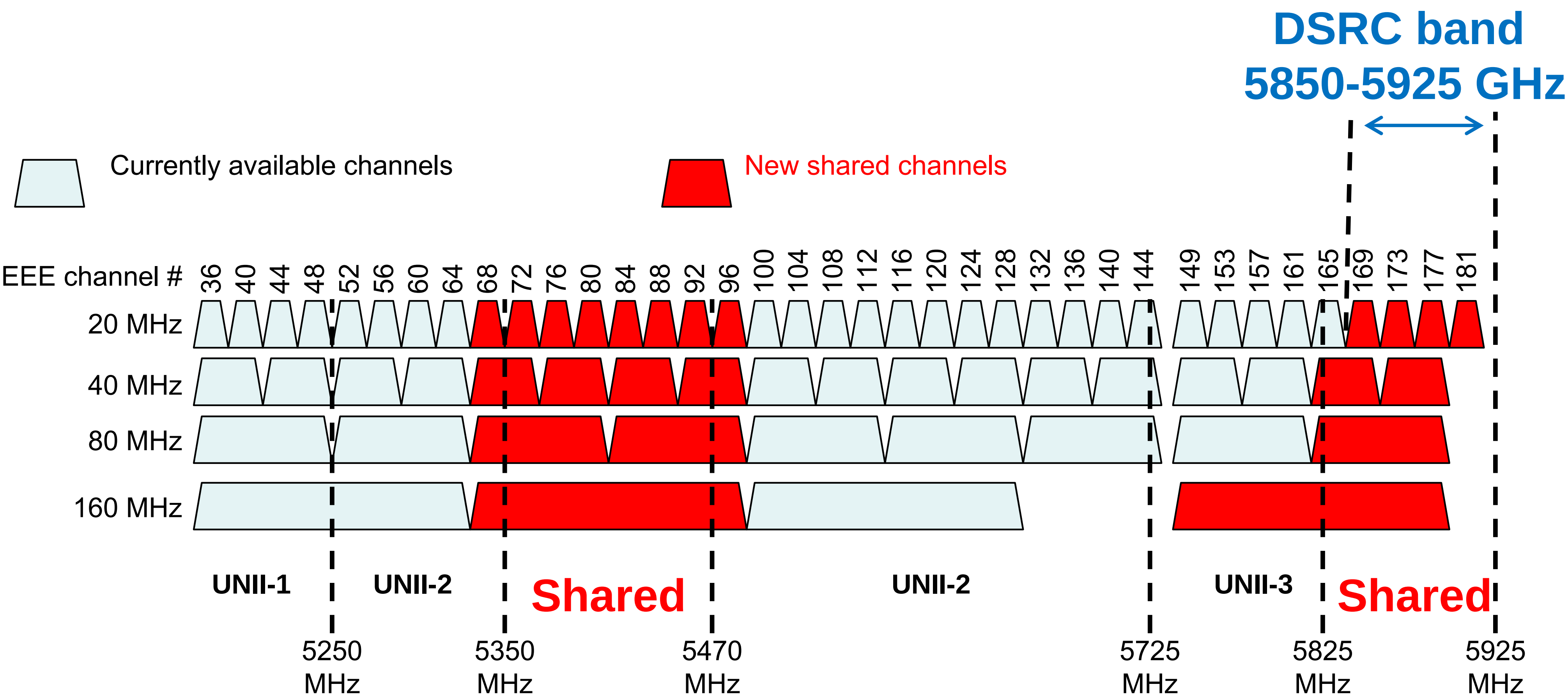
- Fast motion of radios
- Fast motion of reflectors
- Challenging multipath conditions
  - E.g. urban tunnels can result in long delays on strong multipath reflections that 802.11 OFDM is not designed to handle*
- Data traffic congestion scenarios
  - High density of radios and ‘hidden node’ scenarios could cause inefficiencies in the 802.11 CSMA/CA protocol, which in turn could result in a high PER

* Described by 3GPP Urban Macro and Urban Micro channel models

CSMA/CA = carrier sense multiple access with collision avoidance
PER = packet error rate
OFDM = orthogonal frequency division multiplexing

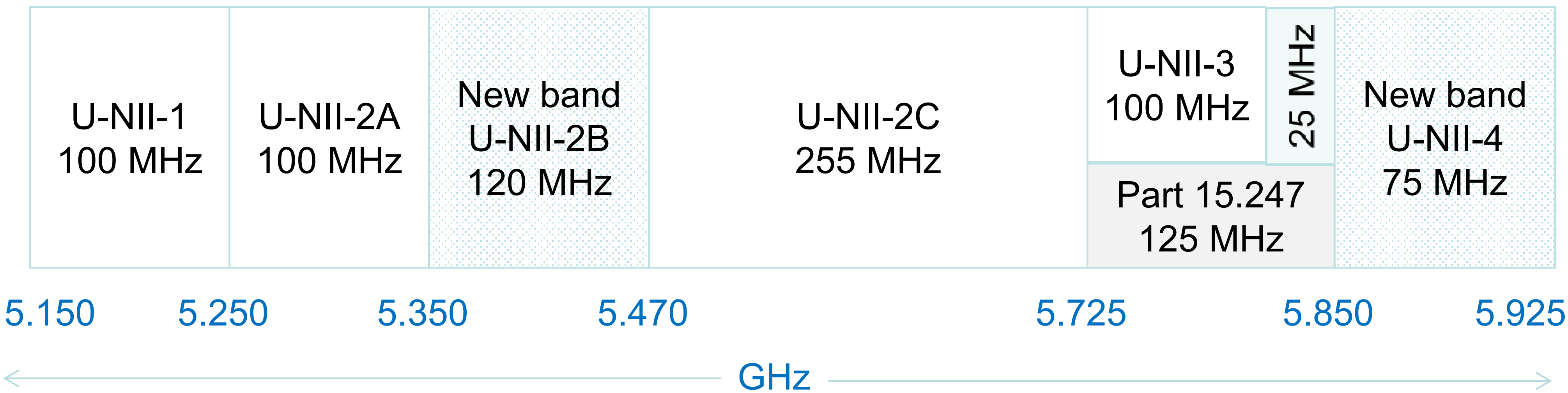
DSRC Band Candidate for Spectrum Sharing

FCC initiative for spectrum sharing: http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-13-22A1.pdf



UNII = Unlicensed National Information Infrastructure

U-NII Band

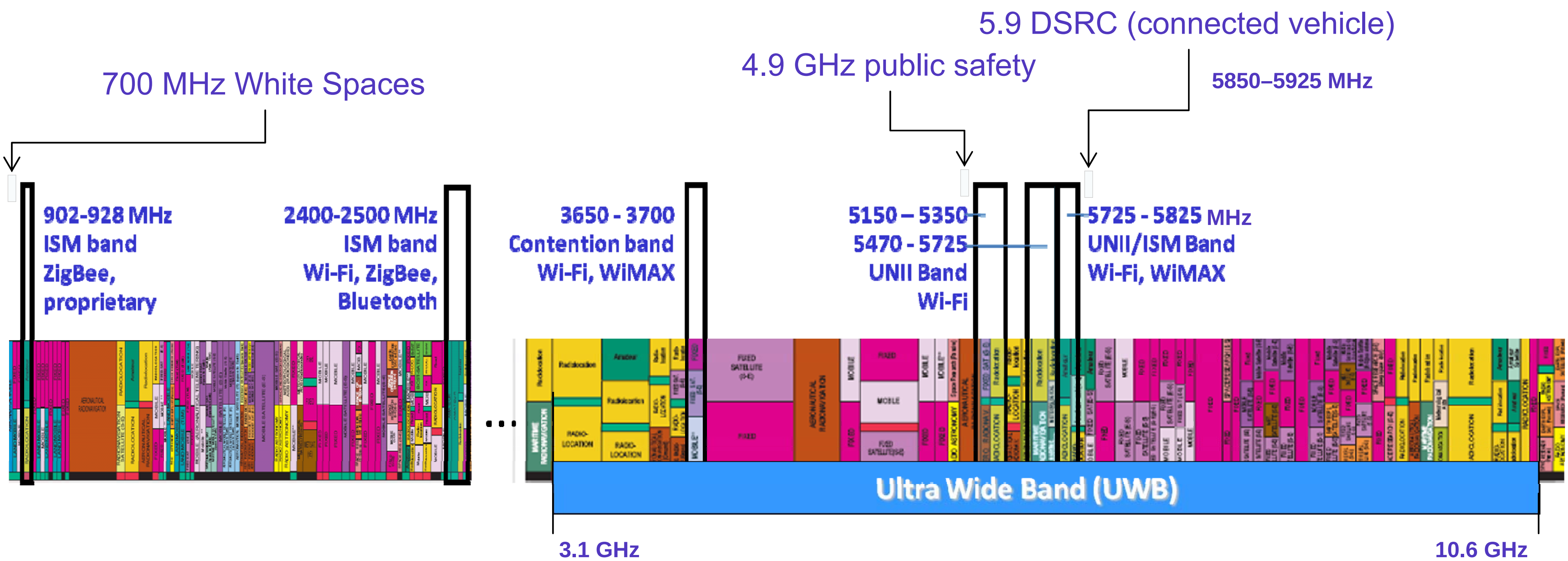


- U-NII-1 = 5150-5250
- U-NII-2A = 5250-5350
- U-NII-2B = 5350-5470 NEW
- U-NII-2C = 5470-5725
- U-NII-3 = 5725-5825 (NEW Proposal to extend to 5850)
- U-NII-4 = 5850-5925 (NEW)

IEEE 802 TAG-18 (aka RR-TAG) regulatory TAG working with the FCC is responsible for the spectrum issues.

UNII = Unlicensed National Information Infrastructure
TAG = technical advisory group
FCC = federal communications commission

Key Unlicensed Bands

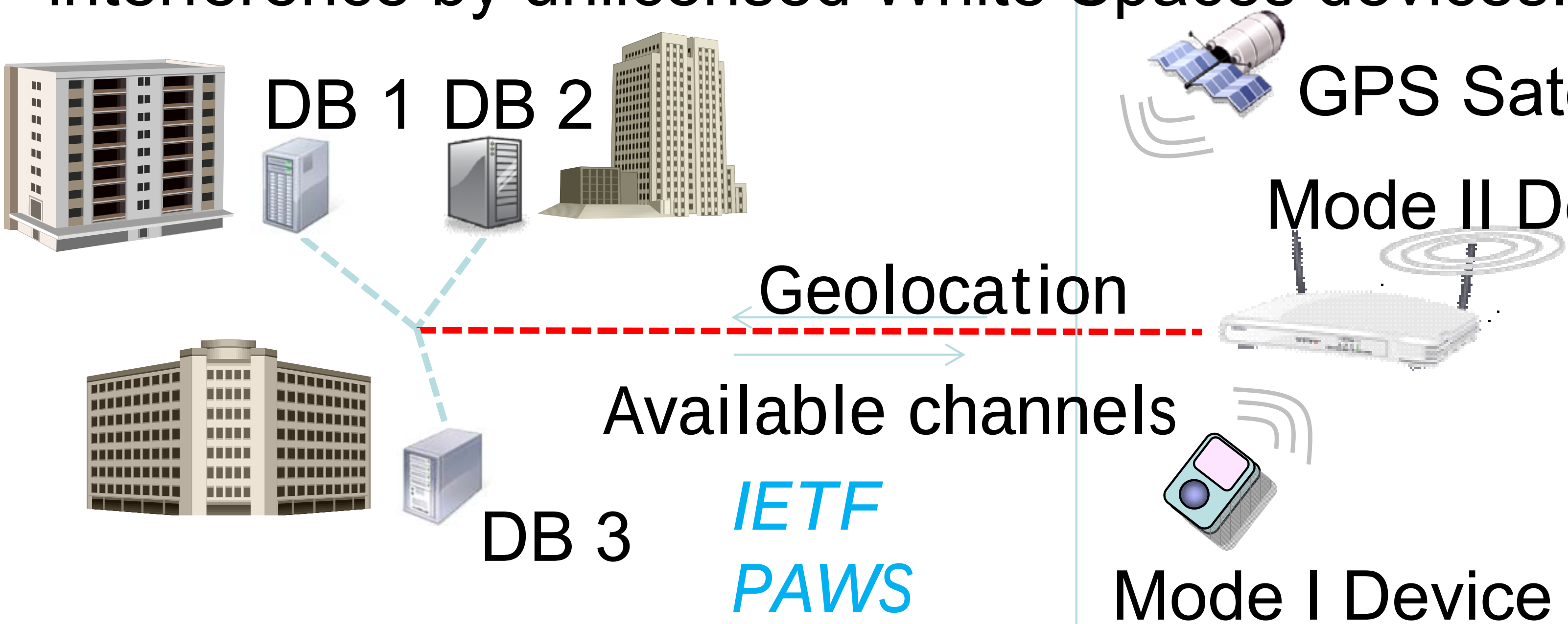


DSRC = direct short range communications

FCC spectrum allocation chart
http://www.ntia.doc.gov/osmhome/allochrt.PDF

White Space Spectrum Access

Spectrum access is database-driven. Database is designed to protect licensed TV transmitters from interference by unlicensed White Spaces devices.



Source: Neal Mellen, TDK

IETF = internet engineering task force
PAWS = protocol to access white space

IEEE 802.11 Very High Throughput

- TGac
  - Under 6 GHz (2.4 and 5 GHz bands)
  - Up to 6.9 Gbps
  - Higher order MIMO (> 4x4)
  - 8 spatial streams
  - Multi-user (MU) MIMO
- TGad
  - 60 GHz band
  - Up to 6.8 Gbps
  - Capitalized on work already done by 802.15.3c in the 60 GHz band
  - Beamforming

VHT = very high throughput

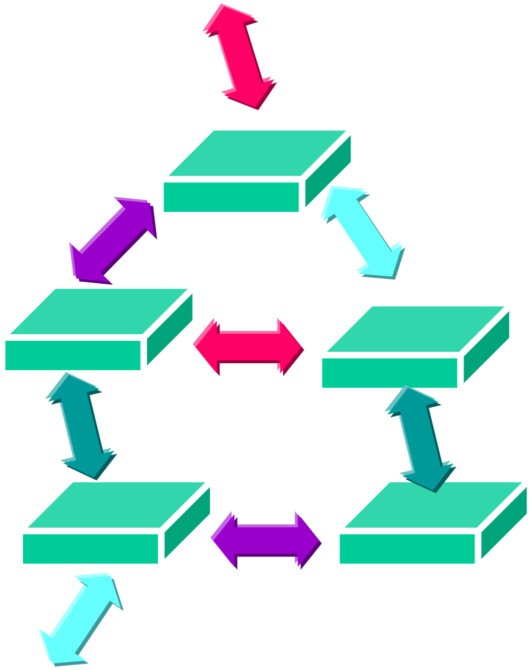
Video Throughput

Format	Average throughput	
	480i60	1080p30
MPEG-2	8 Mbps	20 Mbps
MPEG-4 Part 2	5 Mbps	12 Mbps
HDMI 24-bit color	742.5 Mbps	1.485 Gbps
HDMI 30-bit color		1.86 Gbps
HDMI 36-bit color		2.23 Gbps
HDMI 48-bit color		2.97 Gbps

HDMI throughput figures come from HDMI.org [13]

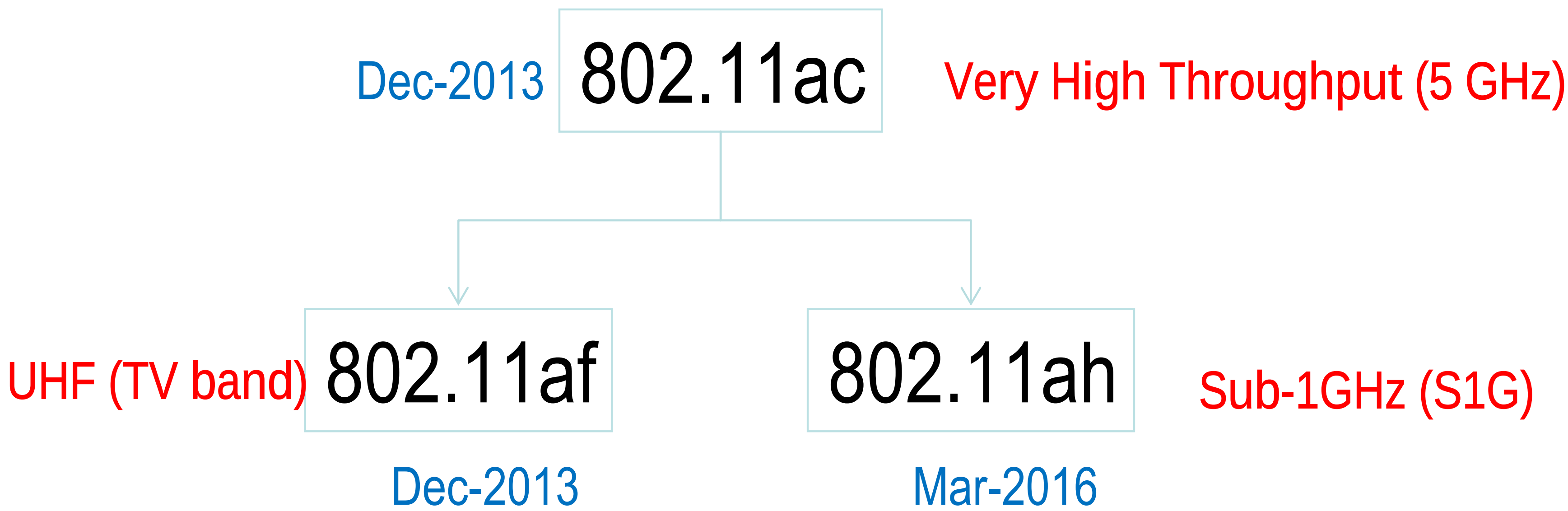
Wireless Mesh

- Self-healing, self-forming
- Throughput, QoS vs. *hops*
- Throughput, QoS vs. *range*
- Routing efficiency
- Throughput is cut in half per hop in a single-RF channel mesh
- Multi-radio mesh nodes communicate on different channels with multiple neighbors simultaneously



For bandwidth-demanding video distribution over mesh the last two bullets are important to consider

802.11ac and Long Distance af/ah



- 802.11af/ah derive their specifications from 802.11ac
- Operation of 11af and 11ah is under 1 GHz
- Support for longer delay spread outdoor deployments

S1G = sub 1 GHz

802.11ah (S1G)

- Goal is to enable WLAN devices to operate in the unlicensed frequency bands below 1 GHz, except TV bands
- Mandatory bandwidths are 1 and 2 MHz; optional bandwidths are 4, 8, and 16 MHz
- Optional support for 2, 3, or 4 spatial streams
- Hi Doppler: optional implementation of traveling pilots (similar to 802.15.4g), used to enable better channel estimation when there is a high Doppler effect (e.g. reflections from vehicles)
- In the WFA an 802.11ah ER MTG has been started and is considering proposals for use cases
- WFA CWG is a joint effort with CTIA to define a test plan for devices that contain both cellular and Wi-Fi radios

S1G = sub 1 GHz
WFA = Wi-Fi Alliance
MTG = marketing task group
ER = extended range

IEEE 802

802.11 Emerging Standards

	Overview	Key Specifications			Expected Completion
		Rate	Range	Velocity	
TGah	Operation in 900 MHz band	802.11n/ac rates scaled to channel	5 km		Mar 2016
TGai	Fast initial link setup	Fast initialization (target 100 ms)		>200 km/hr	Mar 2016
TGaj	China Mili-Meter Wave	Channel bandwidth of 1.08 GHz in the 60 GHz band per Chinese regulatory requirements vs. 11ad channels of 2.16 GHz			Jun 2016
TGak	General Link				May 2016
TGaq	Pre-Association Discovery	Select AP that provides needed services			Jul 2016
TGax	High Efficiency WLAN (HEW)				Mar 2019

Summary

- Many standards – exponential progress in technology
- OFDM and MIMO common to 802.11 and LTE
- Economies of scale bringing low cost of devices
- 802.11
  - Pioneered OFDM and MIMO
  - Widest channels (80 and 160 MHz wide)
- All-IP wireless network architecture makes it easy for Wi-Fi and LTE to interconnect

References

1. IEEE P802.11-REVmc/D2.3, “Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications”, December 2013
2. IEEE IEEE Std 802.11ac™-2013, “Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications; Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz”, December 2013
3. IEEE, 802.11-03/940r4: TGn Channel Models; May 10, 2004
4. IEEE, 11-09-0569 , “TGac Channel Model Addendum Supporting Material”, May 2009
5. TS 25.101, Annex B, “User Equipment (UE) radio transmission and reception (FDD)”,
6. TS 36.101, Annex B, “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception”
7. TS 36.521-1, Annex B, “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification Radio transmission and reception Part 1: Conformance Testing”
8. TS 45.005, Annex C, “GSM/EDGE Radio Access Network; Radio transmission and reception”
9. TS 51.010-1, “Mobile Station (MS) conformance specification; Part 1: Conformance specification”
10. 3GPP TR 37.977 V1.2.0 (2013-11), “Verification of radiated multi-antenna reception performance of User Equipment (UE)”, Release 12, November 2013
11. CTIA, “Test Plan for Mobile Station Over the Air Performance - Method of Measurement for Radiated RF Power and Receiver Performance”, Revision 3.1, January 2011
12. “802.11 Data Rate Computation” spreadsheet, 12/2013, http://www.octoscope.com/cgi-bin/start.cgi/Array_Pages/Entrance_RequestArticles.html?SourceCode=Whitepapers
13. http://www.hdmi.org/devcon2009/Tektronix_Simplify_the_Latest_HDMI_Compliance_Testing_091809.pdf

Data Center Standards

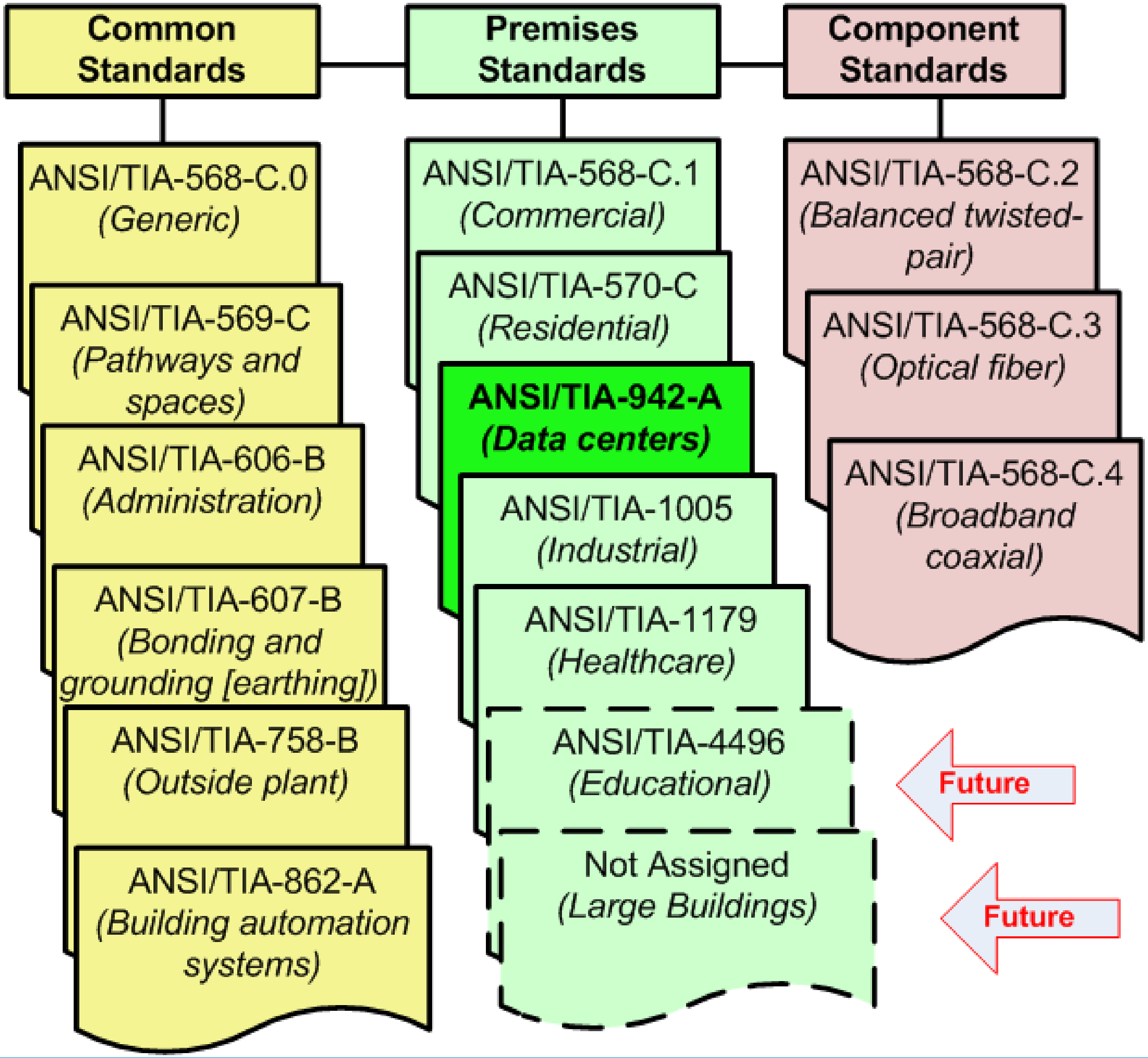
Chris DiMinico MC Communications/Panduit
cdiminico@ieee.org

Data Center Standards

- ANSI/TIA-942 Telecommunications Infrastructure Standard for Data Centers
  - Co-chairs: Chris DiMinico & Jonathan Jew
  - Published 2005 – available through TIA at www.tiaonline.org
  - Revision ANSI/TIA-942-A – Published October 2012
  - Revision ANSI/TIA-942-A – addendum 1 Published February 2013

- ANSI/NECA/BICSI-002 Data Center Design and Implementation Best Practices
  - co-chairs: Jonathan Jew & John Kacperski
  - best practices – complements TIA-942

TIA/TR42 Cabling Standards - ANSI/TIA-942-A



Elements of 942-A - Data Center Standard

- Cabling Design
- Facility Design
- Network Design

- Informative annex's: Provide best practices
  - Annex A - Cabling Design Considerations
  - Annex B - Access provider information
  - Annex C - Coordination of equipment plans with other engineers
  - Annex D - Data center space considerations
  - Annex E - Data center site selection and building design
  - Annex F - Data center infrastructure tiers
  - Annex G - Data center design examples
  - Annex H - Bibliography

Design Elements

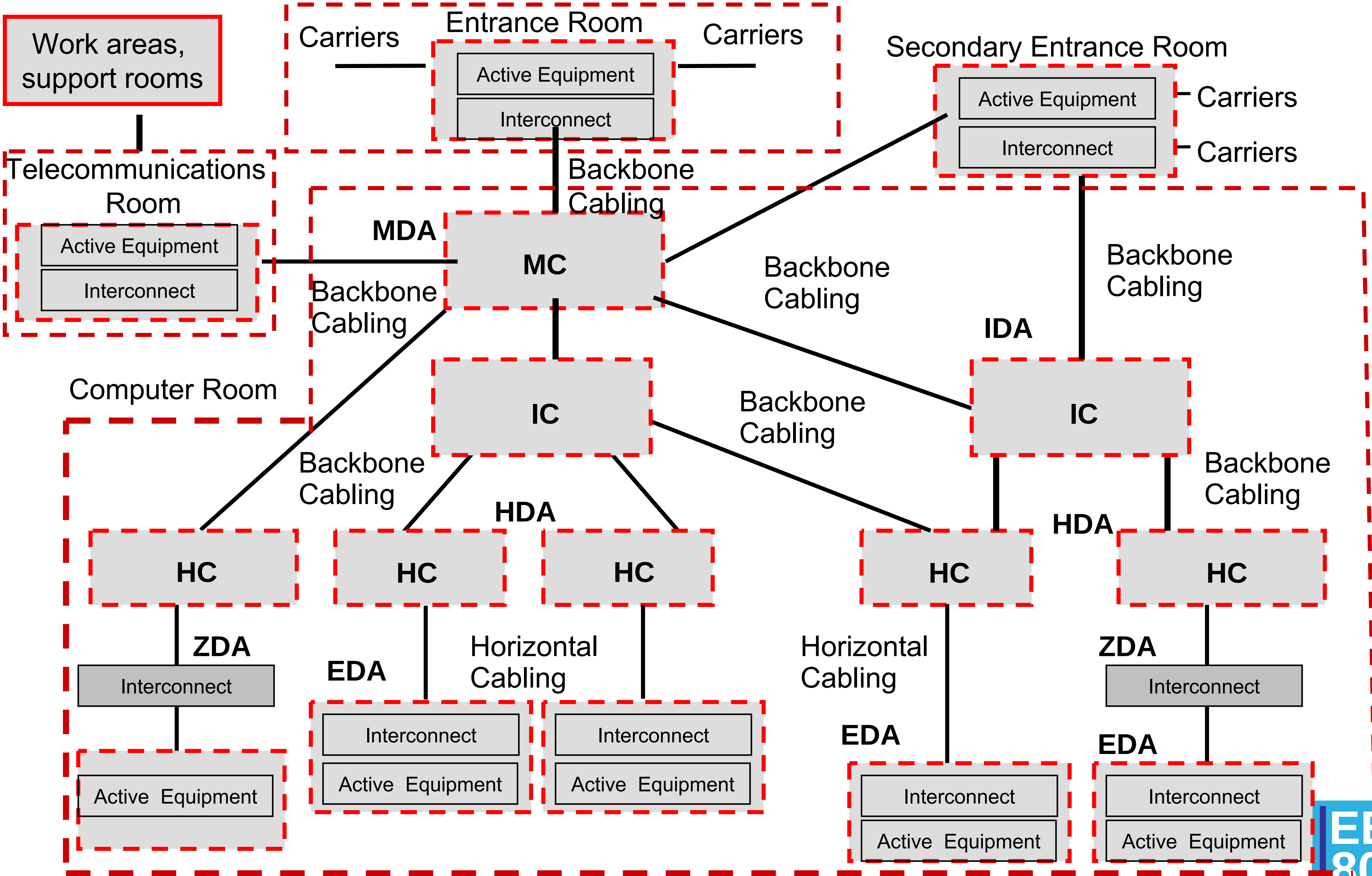
- Cabling Design:
  - Copper and fiber cabling performance
  - Connectors, cables, distribution hardware
  - Cabling distances
  - Space management

- Facility Design:
  - Data center sizing
  - Power distribution methodologies
  - Pathways and spaces
  - HVAC, security, operations, and administration.
  - Flexibility, scalability, reliability and space management

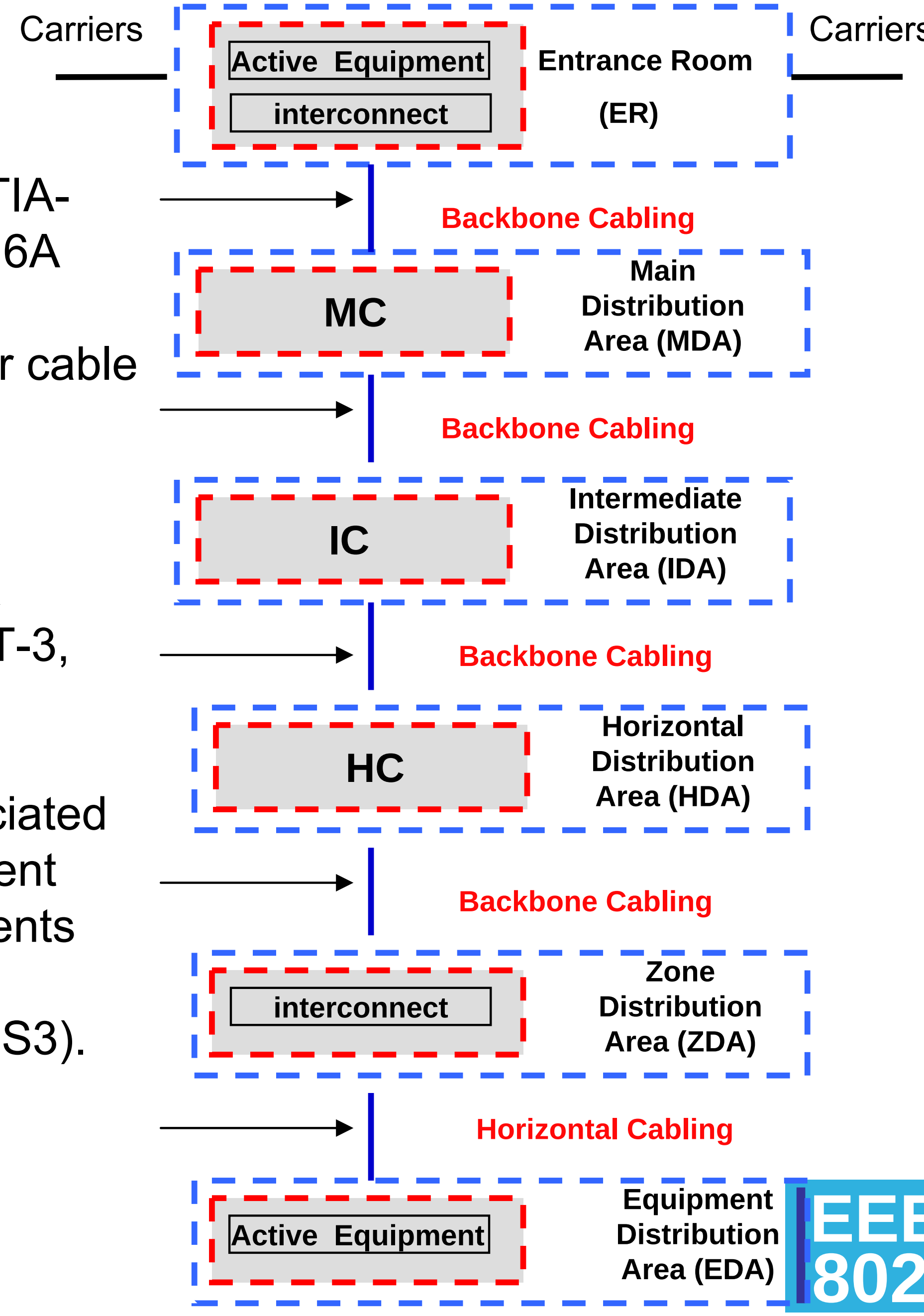
Design Elements

- Network Design:
  - Support of legacy systems.
  - Enable rapid deployment of new and emerging technologies such as ’10 GbE, 40 GbE,100 GbE and 400 GbE applications.

942-A Data Center Topology - distributed



Horizontal and Backbone Cables and Channels



Recognized Horizontal and Backbone Cables:

- 4-pair 100-ohm balanced twisted-pair cable (ANSI/TIA-568-C.2) – category 6 or category 6A, with category 6A recommended;
- 850 nm Laser-Optimized 50/125 um multimode fiber cable OM3 or OM4 (ANSI/TIA-568-C.3), with OM4 recommended;
- Single-mode optical fiber cable (ANSI/TIA-568-.3).
- 75-ohm (734 and 735 type) coaxial cable (Telcordia Technologies 1478 GR-139-CORE) – used for T-1, T-3, E-1, and E-3 circuits only.

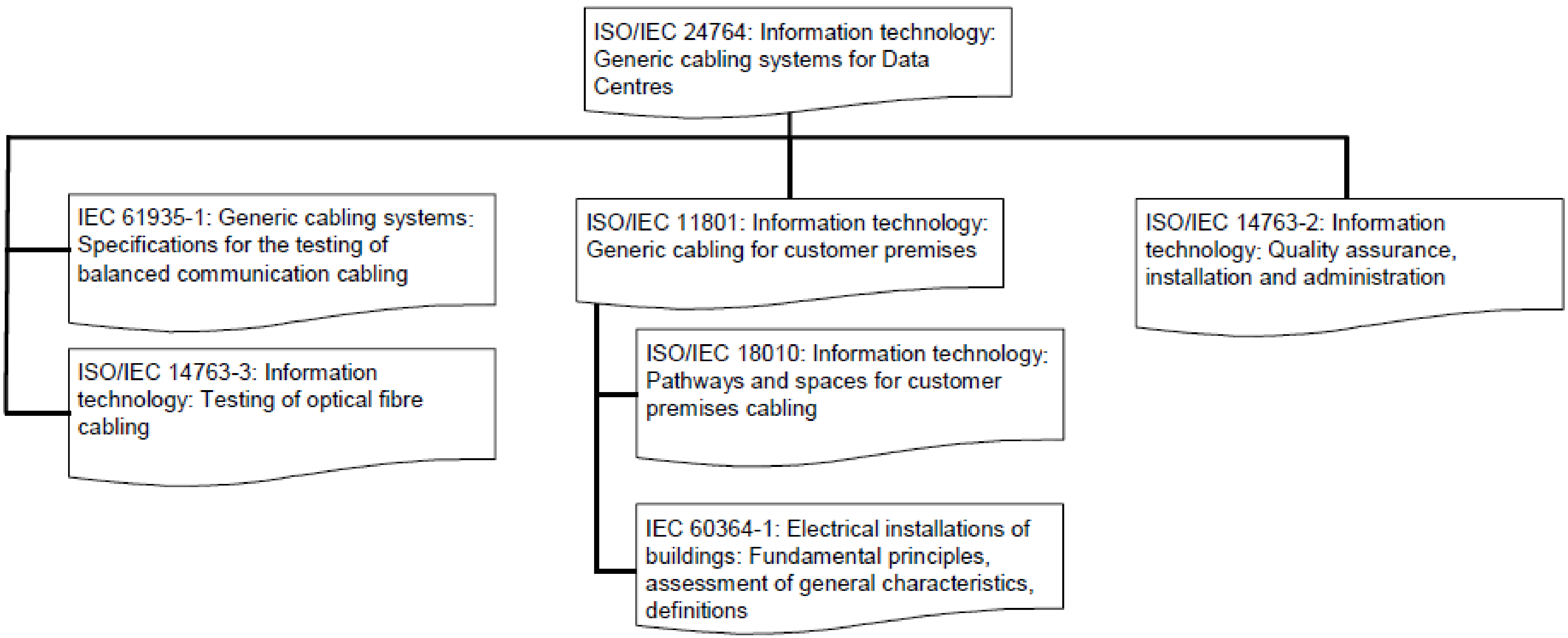
Channels constructed from recognized cables Associated connecting hardware, jumpers, patch cords, equipment cords, and zone area cords shall meet the requirements specified in ANSI/TIA-568-C.0, ANSI/TIA-568-C.2, ANSI/TIA-568-C.3 and ANSI/ATIS-0600404.2002 (DS3).

ISO/IEC - Data Center Standards

- ISO/IEC 24764:2010 - Information technology - Generic cabling systems for data centres
  – Standard published 05/01/2010 by International Organization for Standardization/International Electrotechnical Commission

- ISO/IEC 24764:2010/DAM 1
  – Amendment 1 of ISO/IEC 24764:2010 provides introduction to the intermediate cabling
  – Subsystem and an explanatory annex for the combination of several permanent links to form a single transmission channel.

ISO/IEC Data center standard relationships



Discussions

•Scope review

<u>Scope (proposed):</u>

Forum to discuss substantive basis for applying 802 standards to evolving "IoT" application space and to gather together like minded experts interested in exploring the topic. In keeping with NaB approach the session is to focus on the application of 802 standards to connecting sensors (things) to the Internet "IoT".

Invite other organizations/consortia/standards bodies to participate/collaborate e.g.,

•ODVA
•TIA
•Other..

Discussions

- Next steps
  - White paper topics
    - Sensors for Data Center Management