

# AMI Trials and Testings

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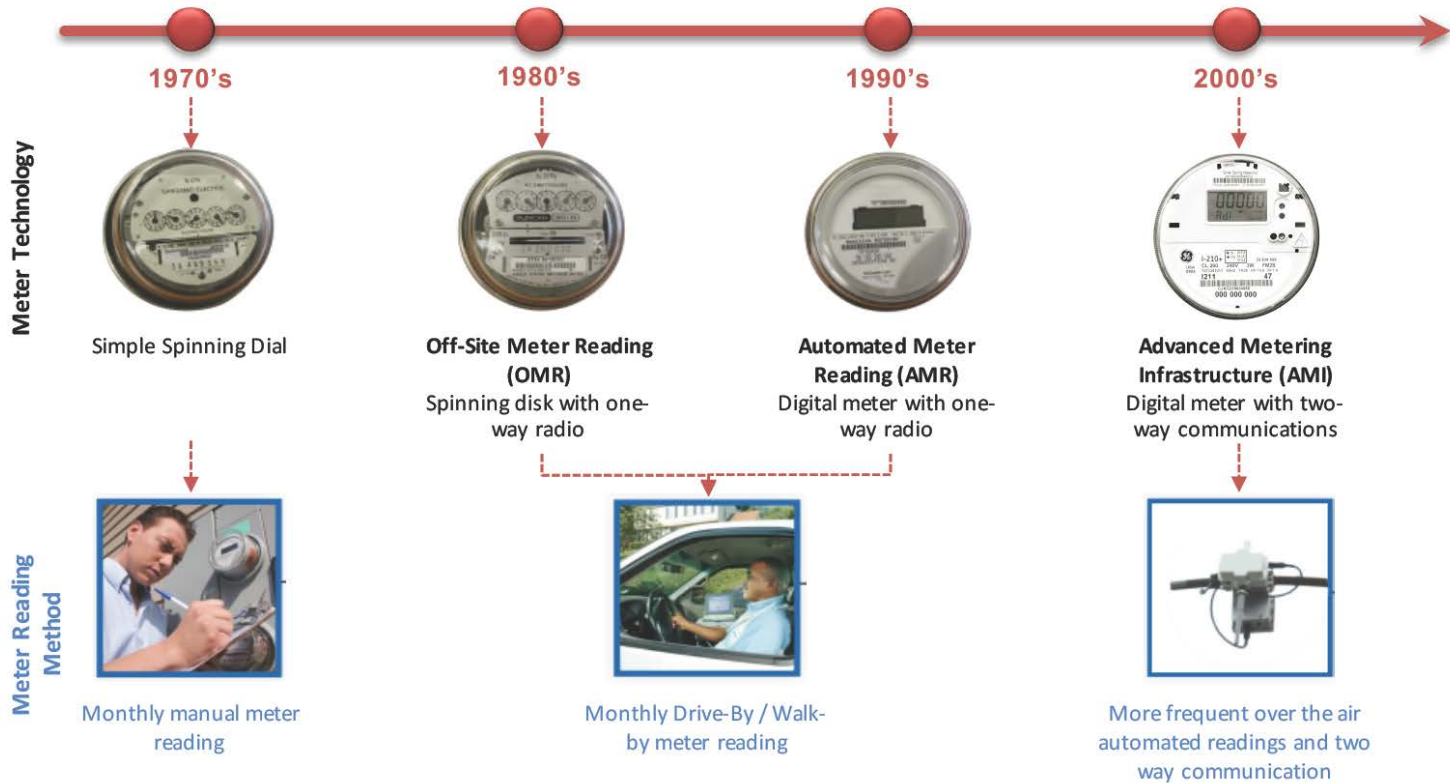


# Xcel AMR => AMI

- **AMR (Automatic Meter Reading) – provides meter reading services only – nearing end of life**
- **AMI (Automated Meter Infrastructure) – provides meter reading services and much more**



## Meter Technology has evolved in the past several decades from manually read electro-mechanical meters to over-the-air digital meters

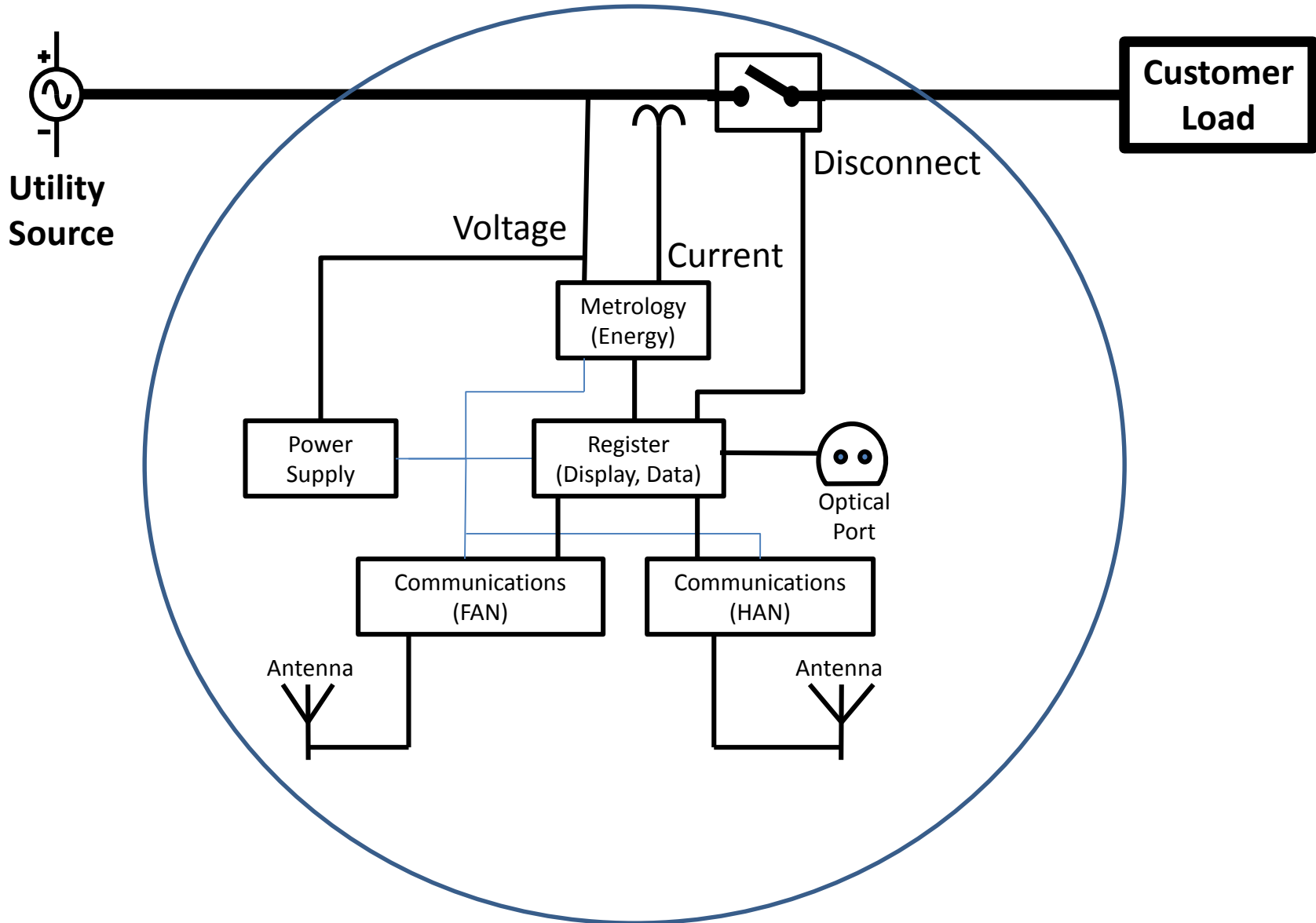


# AMI – aka “Smart Meter”

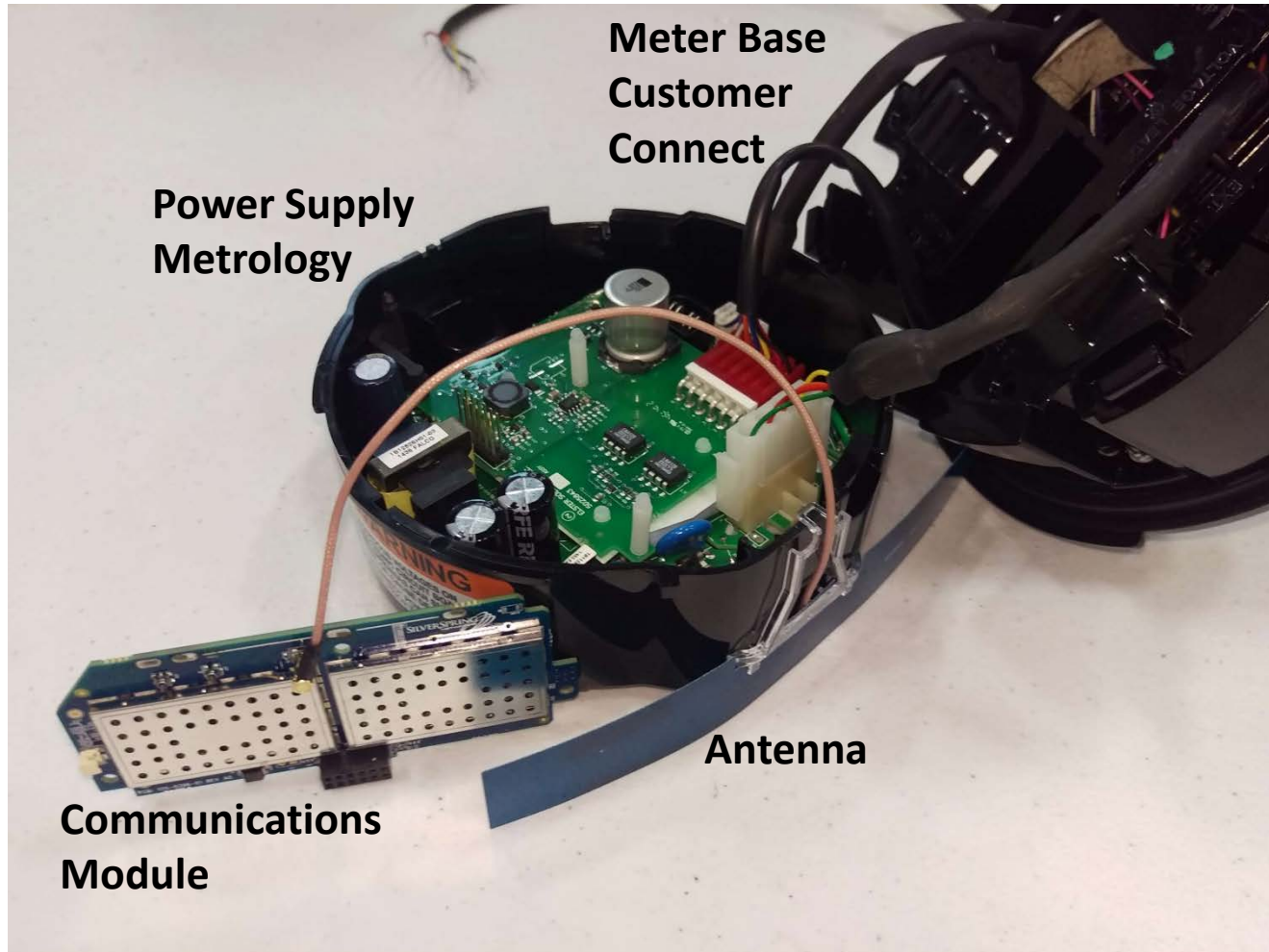
- **Two-way communication adds ability to remotely configure meter, remotely upgrade firmware, remotely diagnose service problems, and provide interval data for all meters.**
- **Some meters designated as “bellwether” meters can provide distribution circuit health information.**
- **Can provide other advanced features as well.**



# Electronic Meter (AMI)



# Typical Meter Breakdown



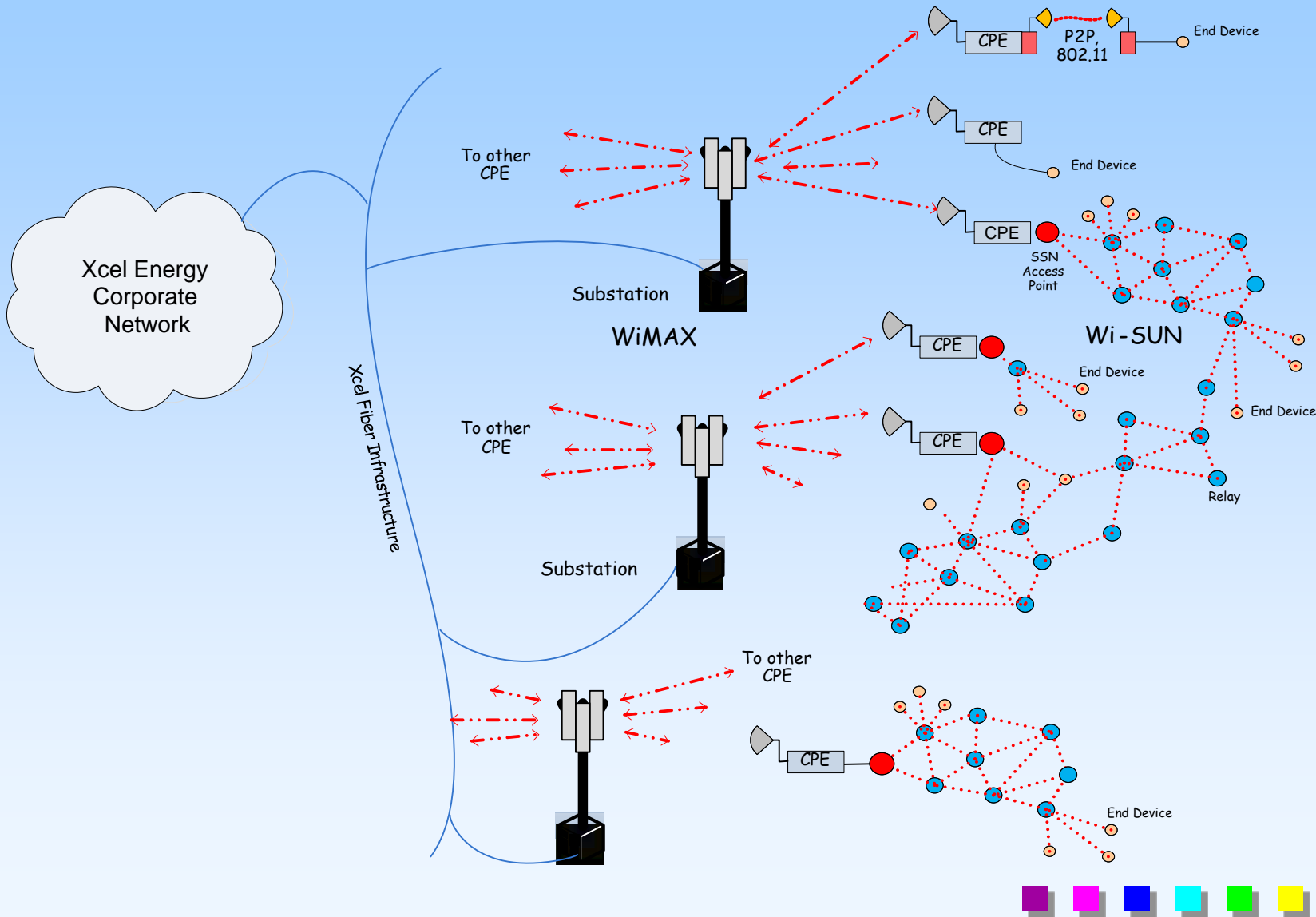
# Xcel's Vision: An integrated communication network as extension to corporate network

- Let's watch a couple of videos explaining this

Hawaii Electric vision: <https://youtu.be/kxemMup3fa4>

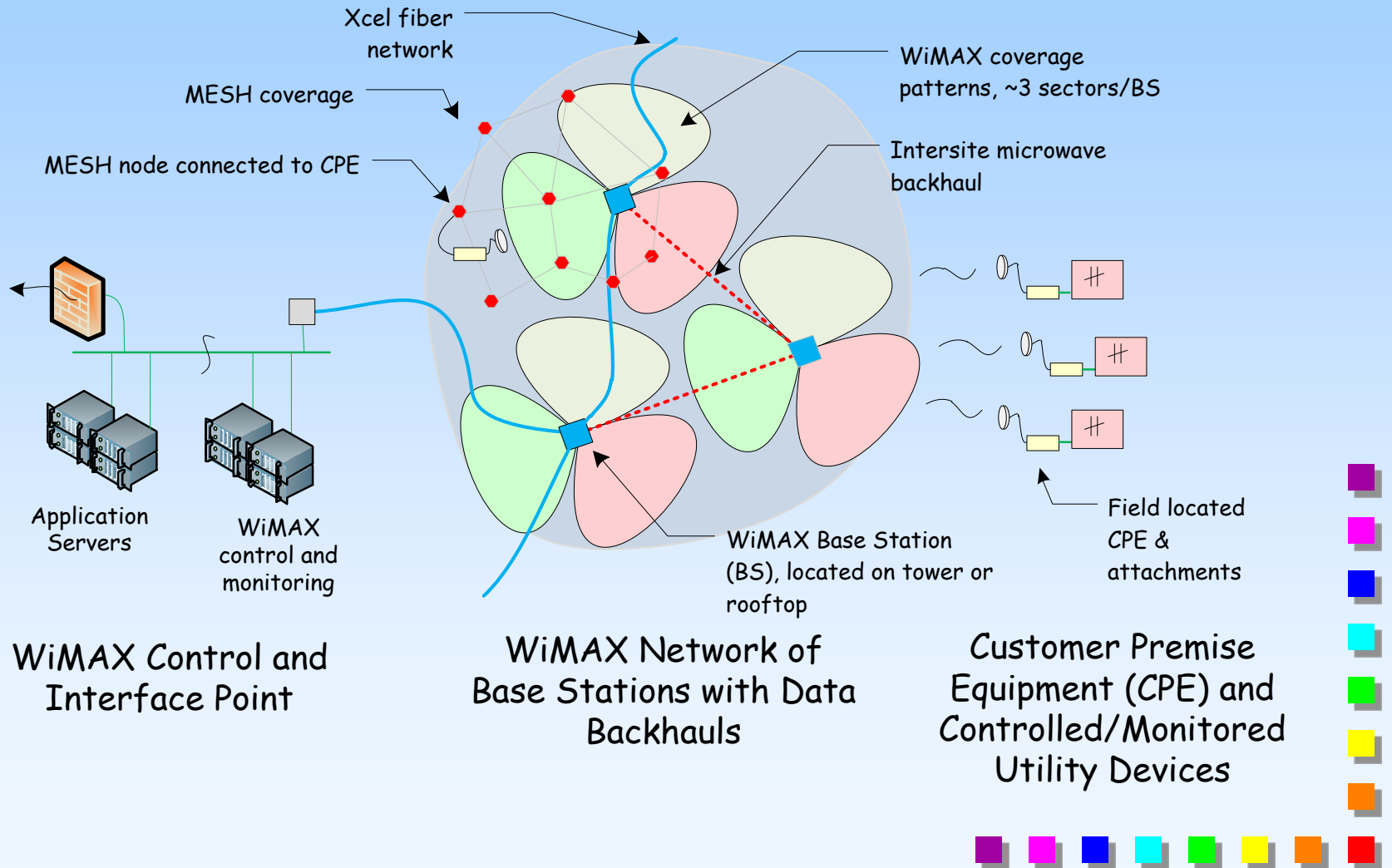
Benefits of Wireless Mesh: <https://youtu.be/0PuOqdHYcTk>

Wi-SUN Vision: [https://youtu.be/B\\_dfHB5kVro](https://youtu.be/B_dfHB5kVro)

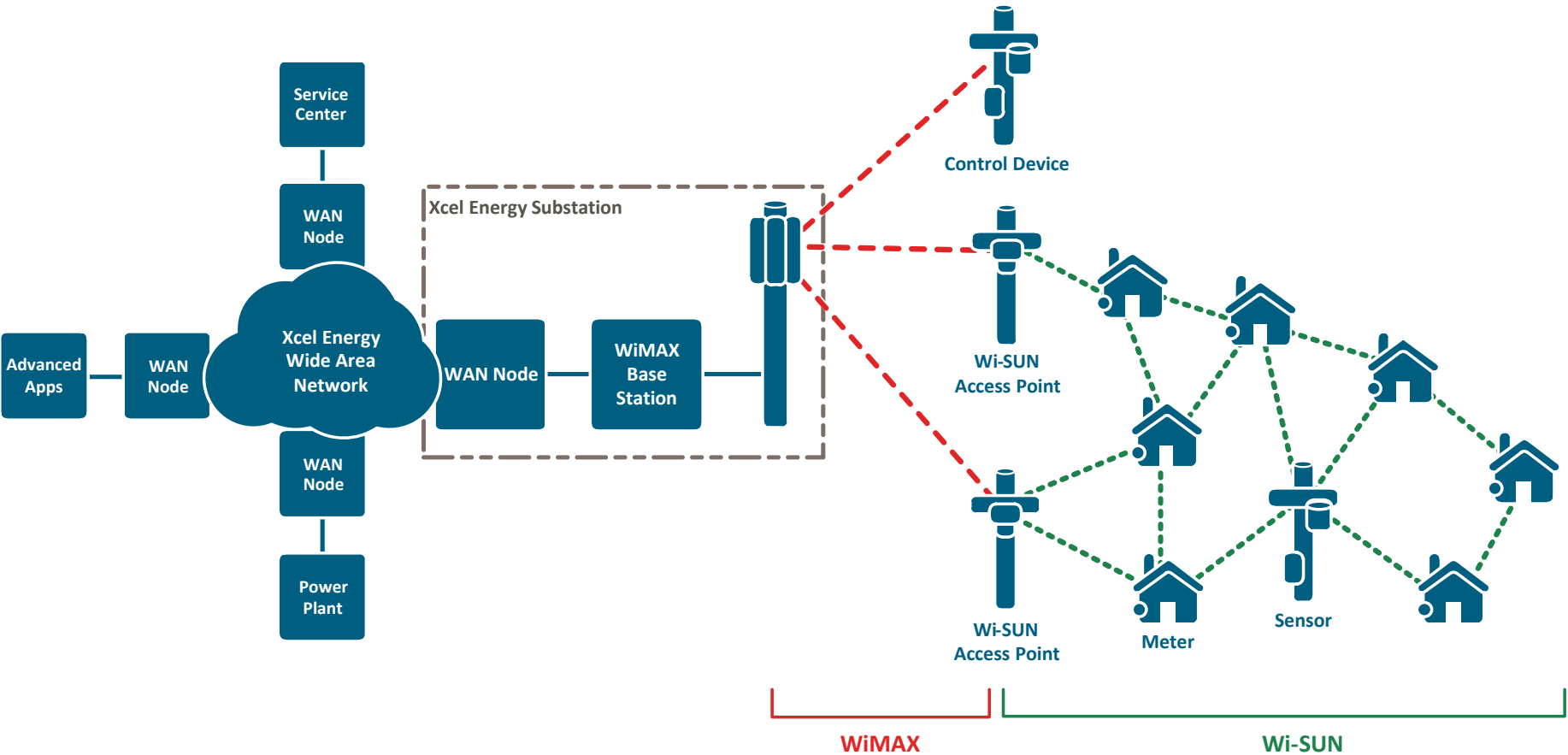




# Typical Configuration for a WiMAX / Wi-SUN Network



# Field Area Network (FAN) Overview



# Xcel Network Design Philosophy

- **Currently IPv4 ( $4.23 \times 10^9$  addresses)**
- **Migrating to IPv6 ( $10^{38}$  addresses possible)**
- **Any point can communicate with any other point using IPv4 today, IPv6 in the future**
- **Three-tier Enterprise / WiMAX / Wi-SUN architecture**
- **Support for best-practice application layer security**
- **Enterprise-level network management**
- **Mixed operations and business traffic with DSCP priority differentiation**
- **Minimize / eliminate the need for application gateways and protocol converters**
- **Any approved applications can use the network to transport information**

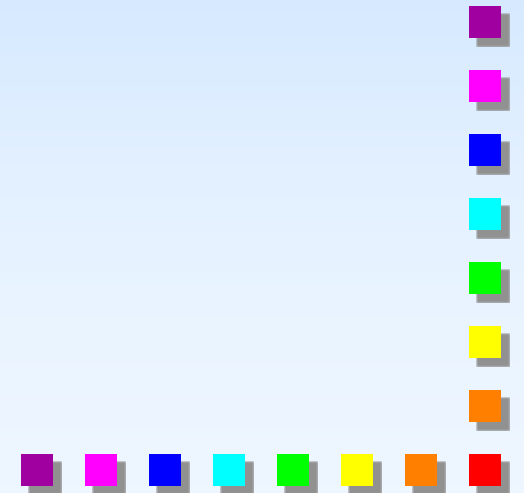


# Speed Requirements for Advanced AMI

- Information- or accounting-only functions can tolerate large delays.
  - “Generate a bill for last month’s consumption” or “How much energy did I consume yesterday”.
  - **Typical four-hour retrieval intervals.**
- Human-factors functions can tolerate modest delays.
  - “Turn-on and turn-off service switch” or “I just turned my stove on or off. What is my consumption rate right now?” **Few seconds**
- Bad things happen to control systems if there is delay in the feedback loop – **Max delays range from few millisecc to seconds, low jitter**
  - Bellwether meters used to manage system voltage profile are useless if too much delay is introduced. Delays in communication used either to execute or manage active control cause such feedback systems to become unstable. Like driving car with one-minute delay on visibility and control.
  - The long delay times and wildly variable jitter observed on some systems during testing are unacceptable for these services.



# Interoperability



# The Problem for Utilities



# HOW STANDARDS PROLIFERATE: (SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC.)



**The nice thing about standards is that there are so many of them to choose from.**

**Andrew Tanenbaum**

# Who Makes Standards, Anyway?



**Interoperability Alliances (WiFi, WiMAX, Wi-SUN)**

**International Standards ( ISO, IEC )**

**National Standards ( ANSI, NIST, IEEE )**

**Industry Standards - formalized practice**

**Industry Practice - informal practice**

**Proprietary Systems - vendor specific**





# What is necessary for Interoperability?

- **Compliance with relevant Standards**
  - Including entire stack from Physical to Application
- **Interoperability Testing**
  - “Plugfests”
- **Certification by independent third party**



# What is a “Profile”?

- A Communication Profile is a list of the standards *and their options* necessary to achieve end-to-end interoperability.
- **Variations in profile between two systems may make them proprietary.**



# Is Security Jeopardized by Interoperability?

- NO
- “Security by Obscurity” is a flawed concept ([https://en.wikipedia.org/wiki/Security\\_through\\_obscurity](https://en.wikipedia.org/wiki/Security_through_obscurity))
- Security principles:
  - Use open, publically scrutinized security practices – they are more secure than proprietary schemes that don’t receive such scrutiny
  - Publish *how* security is done.
  - DO NOT Publish the Key
  - ..... Just like we do with locks and keys.



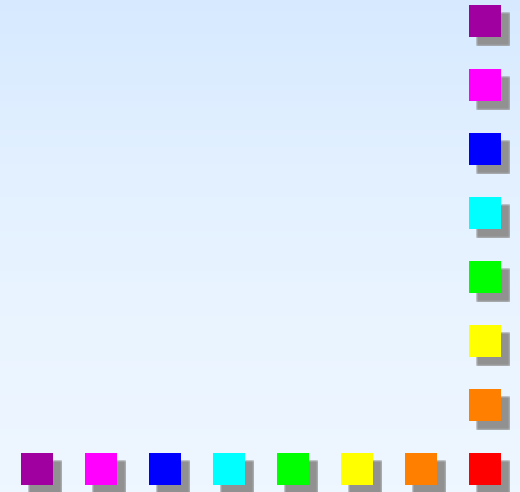
# Standards for DA and Metering

- IEEE 802.15.4g for Wireless Mesh (Physical and Transport)
- RS232 (Physical Layer)
- Ethernet (Physical Layer)
- Internet Engineering Task Force (Internet Standards) (Transport through Application)
- ANSI C12.18, C12.19, C12.22 for metering (Application Layer)
- DNP 3.0 for DA and SCADA (Application Layer)
- IEC 61850 for DA and SCADA (Application Layer)



# Interoperability Success Stories

- Bar Codes
- Wi-Fi
- WiMAX
- DNP
- IEC 61850
- And Many More.....



# Interoperability Promised

- **ANSI C12.18, C12.19, C12.22**
  - Non-interoperable interpretations
  - Lack of profile agreements
  - Lack of 3<sup>rd</sup> party testing
- **Wi-SUN**
  - Physical Layer certifications released
  - Transport Layer certifications soon
- **Zigbee**
  - Flawed profile model failed in Zigbee 1.0.
  - (My Opinion) Will be superseded by Internet of Things and Wi-SUN



# Who Certifies?

## ■ Physical and Transport Layers:

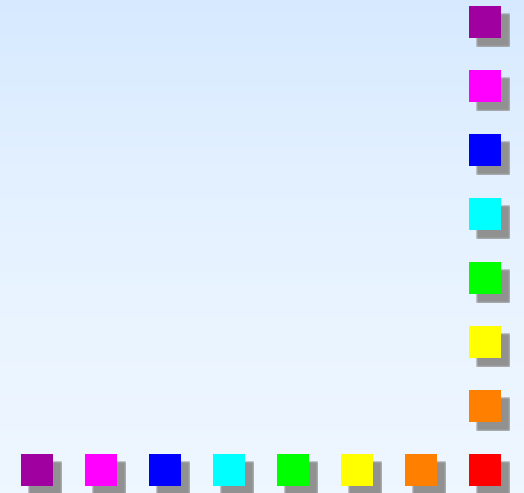
- Wi-Fi Alliance (<http://www.wi-fi.org>) (Physical)
- WiMAX Forum (<http://www.wimaxforum.org/>) (Physical)
- Wireless Smart Utility Networks (Wi-SUN) Alliance (Physical and Transport) (<https://www.wi-sun.org>)
- Internet Engineering Task Force (IETF) (Transport) (<https://www.ietf.org>)

## ■ Application Layer:

- UCA International Users Group for IEC 61850 (Application Layer) (<http://www.ucaiug.org>)
- North American End Device Registration Authority (NAEDRA) for metering (Application Layer) (<http://www.naedra.org>)
- Distributed Network Protocol (DNP) Users Group (Application Layer) (<https://www.dnp.org>)

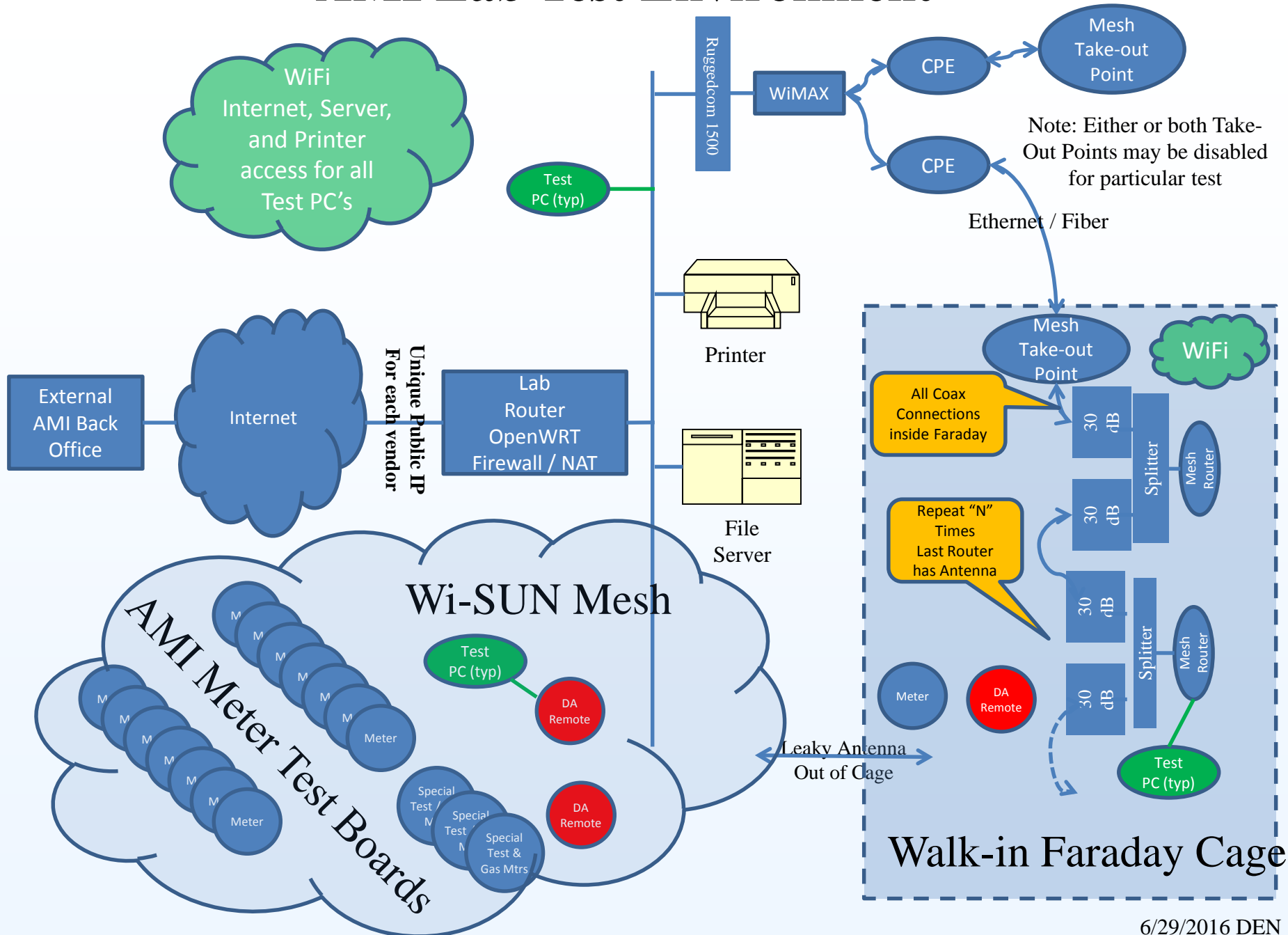


# AMI Testing



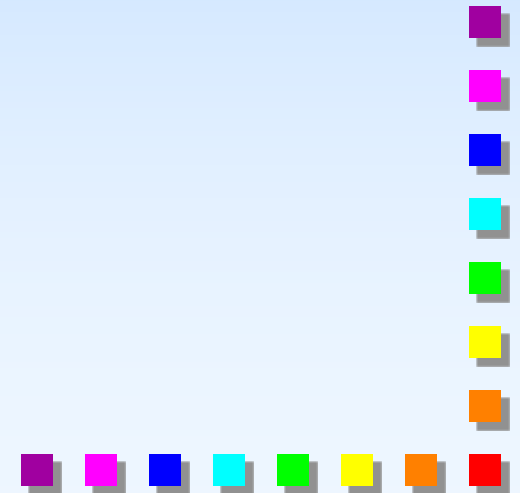


# AMI Lab Test Environment



# Mesh Radio Test

- **Multihop communication:**
  - **Throughput**
  - **Packet Latency**
  - **Packet Jitter**
  - **Packet loss**
- **Priority DA over AMI**
- **Security**
- **Rerouting on Loss of Path**



# AMI Meter Test Outline [1]

- **Basic Metrology: kWh, Watts, kVAr. kVArh, kVA, kVAh, Volts, Vh, V<sup>2</sup>h, Amps, Ah, A<sup>2</sup>h**
- **AMI Functionality:**
  - **Optical Probe**
  - **Mesh Radio**
  - **AMI back office**



# AMI Meter Test Outline [2]

- **Simulated customer interval data: compare optical probe to back office**
- **Whole Service Disconnect: verify restraint**
- **Over-the-air firmware upgrade / downgrade for metrology, register, network**
  - **Security: rejection of adulterated firmware**



# AMI Meter Test Outline [3]

- **Tamper Detect**
- **Service errors: reporting of vectors through local tools and remotely**
- **HAN (Home Area Network) functionality**
  - **Customer notifications**
  - **Customer “machines” interfaces**
  - **Security**



# AMI Meter Test Outline [4]

- **Specialty tests:**
  - **Non-sinusoidal waveform metering accuracy**
  - **Variable load metering accuracy**
  - **Neutral detection**
  - **Phase identification**



# AMI Meter Test Outline [5]

- **Meter timekeeping: “disciplined” clock**
  - **Set the meter to "power system derived" clock. Excite the meter with 59 Hz power. Observe timekeeping and behavior when the clock is "reset" to coincide with "correct" time. Observations to include log files and interval data records.**
  - **Disciplined clock should adjust heartbeat without interval data discontinuities**



# AMI Meter Test Outline [6]

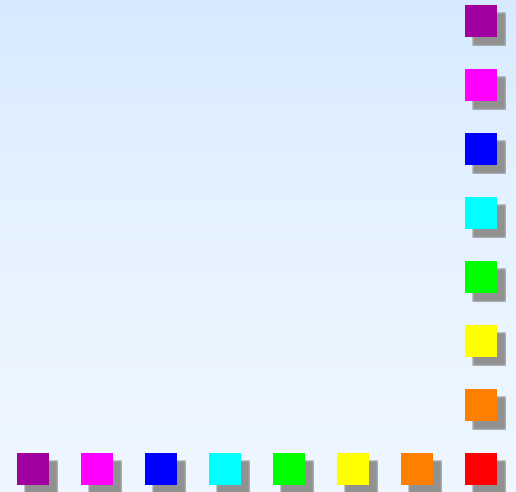
- **Meter energy measurement symmetry.**
  - **Excite meter at 60 Hz potentials but with constantly changing current phase angle. Observe after elapsed time that forward/reverse real and reactive energy are all equal. Accumulated values should all be zero.**





# Additional Functionaity

- **Back Office analytics**
  - **“Non-Technical” Losses**
- **Disconnect switch management**
  - **Demand limiting**



# For Further Reading

- World Without Standards video:  
[https://www.youtube.com/watch?v=TaxWfz\\_MB2A](https://www.youtube.com/watch?v=TaxWfz_MB2A)
- Interoperable Standards: ITSI presentation:  
[http://www.perey.com/ARStandards/\[Wiles\]CTI\\_Interoperability\\_Testing\\_ETSI.pdf](http://www.perey.com/ARStandards/[Wiles]CTI_Interoperability_Testing_ETSI.pdf)
- Consider a world without standards blog:  
<http://www.commscope.com/Blog/Consider-a-World-without-Standards/>
- Wi-SUN overview  
<https://www.wi-sun.org/images/assets/docs/wi-sun-alliance-overview.pdf>
- Wi-SUN video  
[https://www.youtube.com/watch?v=B\\_dfHB5kVro](https://www.youtube.com/watch?v=B_dfHB5kVro)



# ¿ Maswali ?

