Communications for the Smart Grid

March 2012

R. Bryan Seal, P.E.
SmartSynch, Inc

Outline

- Smart Grid Overview
  - What is it
  - Considerations
  - Media Choices
  - Front End to Last Device High Level Architecture
- Into the Sun – Making the Leap Home
  - Public WAN Options
    - Cellular technology overview and development path
    - Objections and answers to cellular communications
- Inside Looking Out – Communications Beyond the Meter
  - IEEE Standards
  - ZigBee Overview
  - Predictions
- Use Cases
- Summary

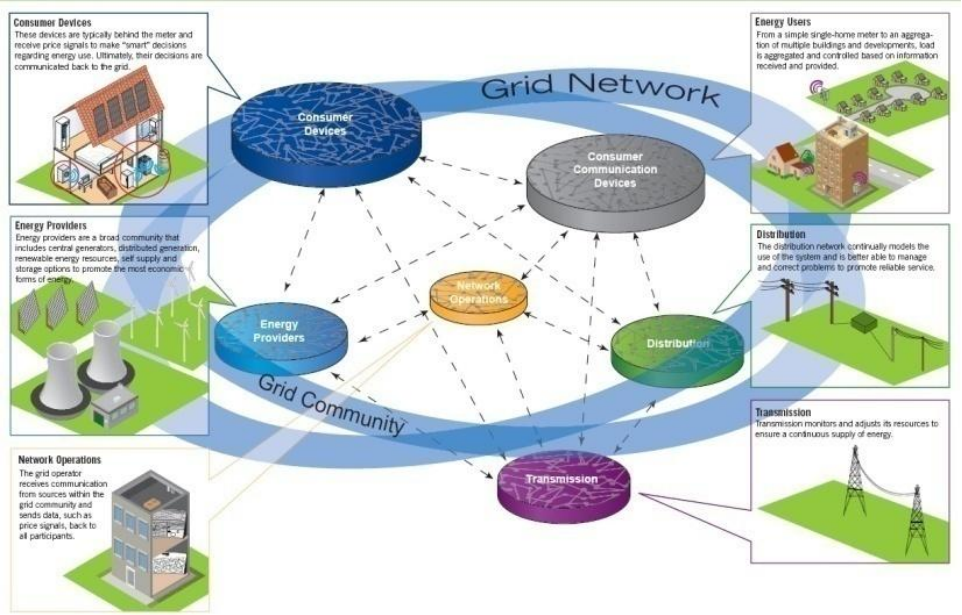
Why Communicate?

Smart Grid is the “siliconization” of the existing power grid to *enable interaction* between generation, transmission and distribution assets on the utility side and customer load and generation assets on the customer side to efficiently meet the total Grid requirements.

Interaction involves all intelligent electronic devices (IEDs), distributed computing elements, and communication with and between IED elements….

Smart Grid Communication Considerations:

- No single communications technology will fit all needs
- Technology will be continually changing
- Need for bandwidth will be ever increasing
- Security requirements will continue to evolve
- Remote end point device management is paramount
- Will require distributed processing of data at lowest possible level
- Interoperability is the Holy Grail

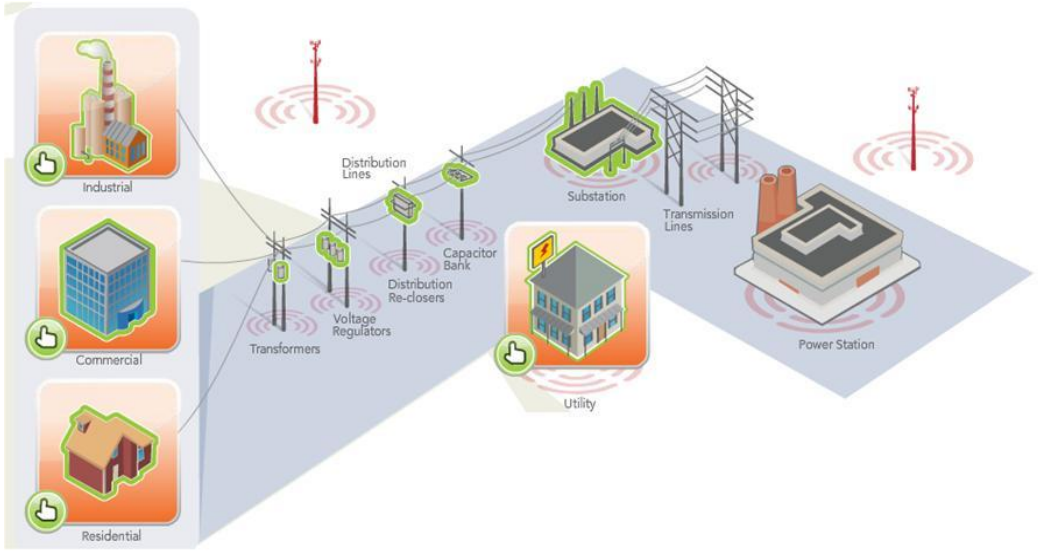


Source http://www2.pjm.com/documents/downloads/strategic-responses/letters/smartgrid.pdf

Interaction involves all intelligent electronic devices (IEDs),distributed computing elements, and communication with and between IED elements....

Smart Grid Communications Media – End to End

- Power Line Carrier
- Wireless Mesh
- Private Wireless Point to Point
- Public Wireless Point to Point (Cellular)
- Fiber

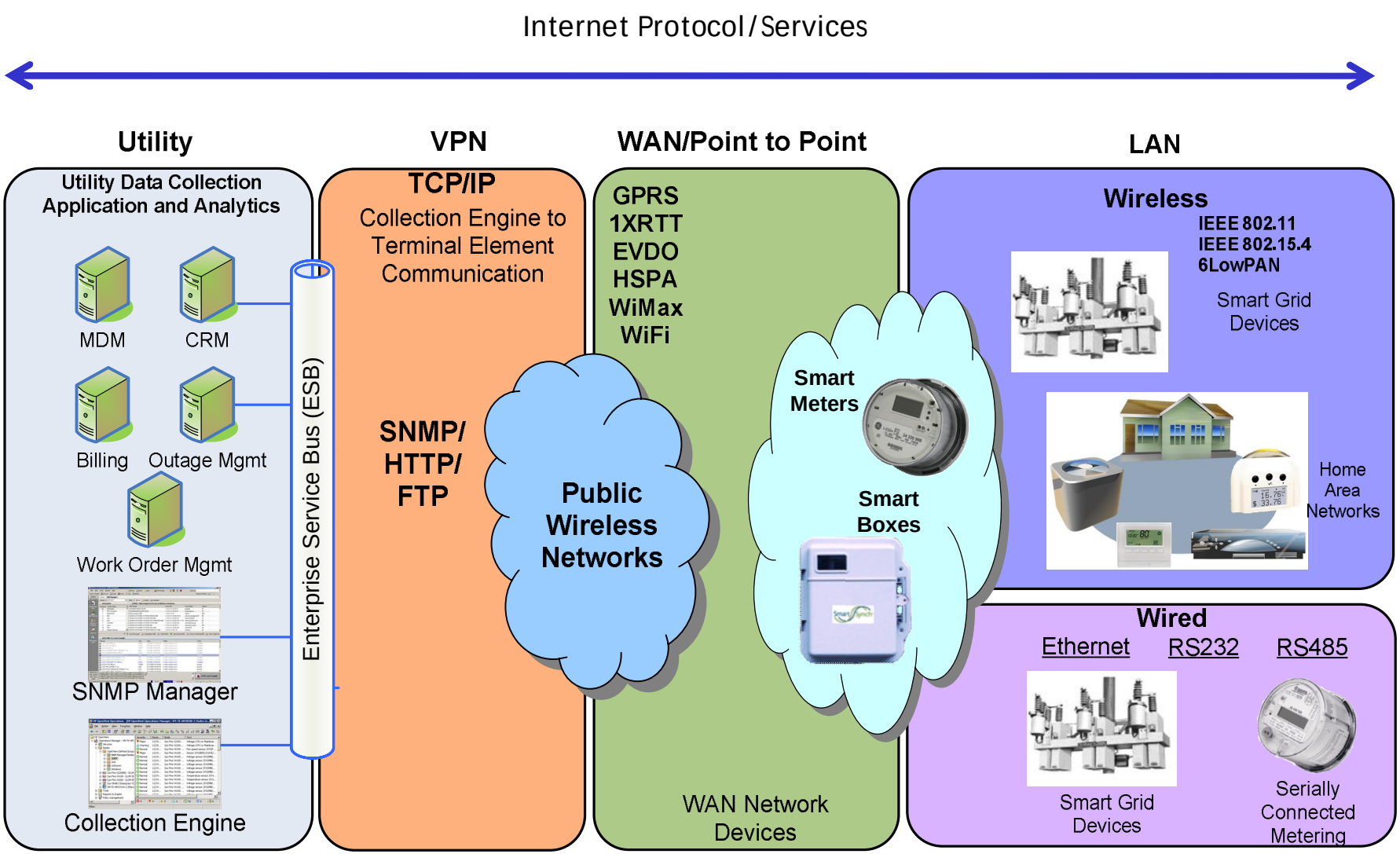


End-Points and Investments by Technology

Technology	2008 Endpoints	2012 Endpoints	2008 Investment	Cumulative 2008 - 2012 Investment
PLC/BPL	17,000,000	20,000,000	$230,000,000	$2,000,000,000
Private Wireless	30,000,000	60,000,000	$300,000,000	$2,250,000,000
Mesh	2,000,000	25,000,000	$100,000,000	$1,260,000,000
Cellular	3,900,000,000	5,000,000,000	$120,000,000,000	$700,000,000,000

Worldwide numbers based on published information and conservative estimates when required

Smart Grid Communications Technology Vision



Into the Sun

"Growing, knowing, you learn more everyday.."
Mark Farner - GFR

GSM Family

- What is it?
  - Global standard for cellular voice and data
- Data evolution:
  - GSM (Global System for Mobile communications)
    - GPRS (General Packet Radio System) 144 kbps peak
    - EDGE (Enhanced Data GSM Environment) 384 kbps peak
  - UMTS (Universal Mobile Telecommunications Service)
    - Utilizes W-CDMA (Wideband Code Division Multiple Access)
    - HSPA (High Speed Packet Access) 14 Mbps/5.8 Mbps down/up peak
      - Supports Quality of Service (QoS) – but not implemented
    - HSPA+ (Evolved HPSA) 56 Mbps/22 Mbps down/up peak
  - LTE (Long Term Evolution) 100/50 Mbps down/up peak
    - Support Quality of Service (QoS)
- Secure private IP segment by Access Point Name (APN) assignment
- US Carriers: AT&T, T-Mobile
- Current install base of 5.2 billion subscribers world wide*

*The Global mobile Suppliers Association

CDMA2000 Family

- What is it?
  - CDMA: Code Division Multiple Access
  - Qualcomm-backed standard for cellular voice and data
- Data evolution: 1xRTT – EVDO – UMB
  - 1XRTT: 1 pair -1.25MHz Radio Transmission Technology
    - 144 Kbps peak
  - EVDO: Evolution, Data Optimized
    - 1.9/3.9 Mbps up/down peak
  - UMB: Ultra Mobile Broadband
    - 280 Mbps , QualComm not supporting!
    - Allows QoS (if carrier supported)
- US Carriers: Verizon, Sprint
- Current install base of around roughly 200 million users
- Incompatible with GSM family
- Secure Private IP segments available

WiMAX

- What is it?
  - Worldwide Interoperability for Microwave Access (WiMAX)
  - IEEE 802.16
  - Good throughput (40 Mbps on current standard)
  - Robust QoS (quality of service) capabilities

- US Carriers: Sprint

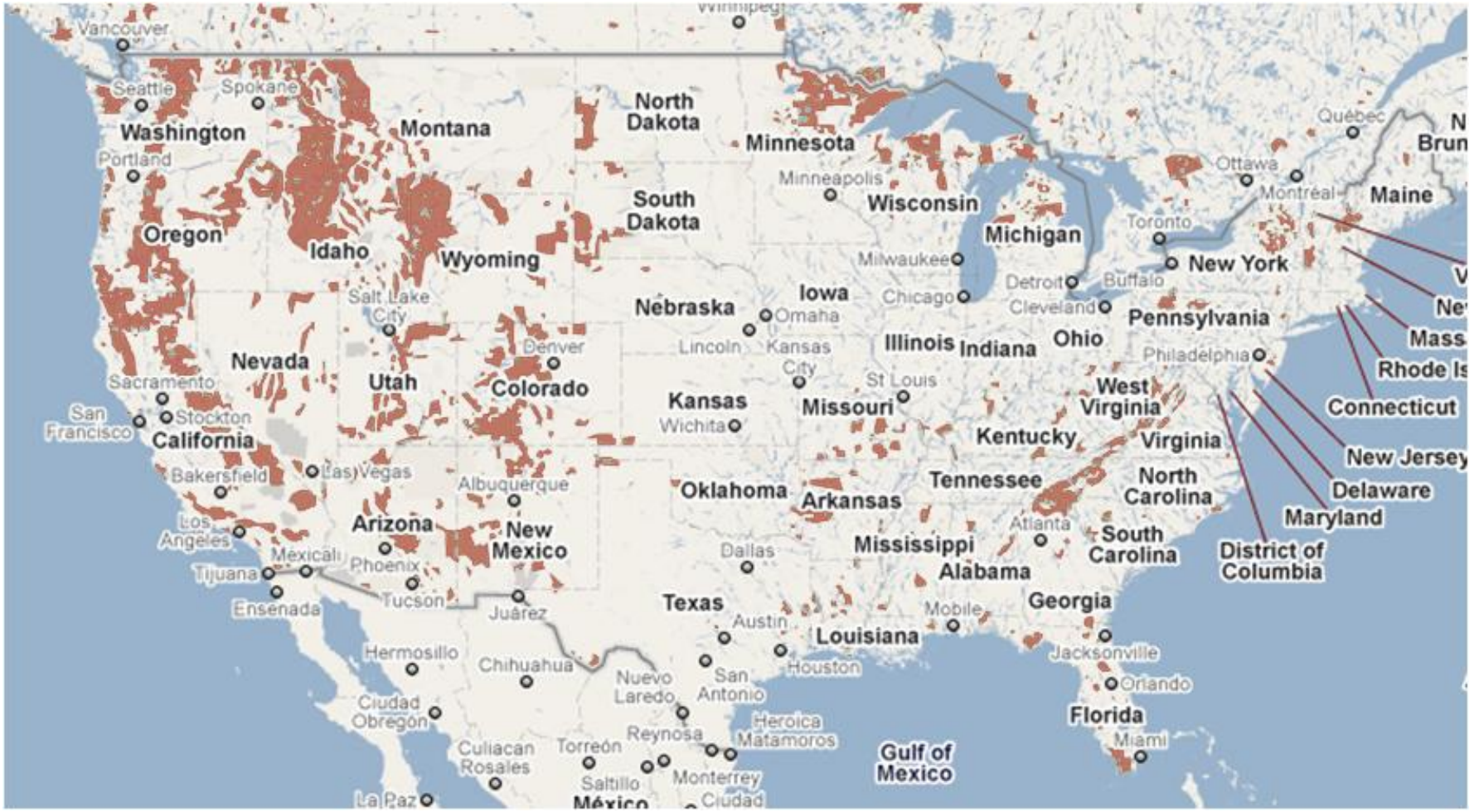
- Also - great solution for private radio, critical infrastructure

Cellular Hurdles in Smart Grid

- I don’t have coverage
- It isn’t reliable enough
- I may not have bandwidth when I need it
- It is not secure
- It changes too much
- I can manage it better myself
- It cost too much

I Don't Have Coverage

U.S Cellular "Holes" Map



Source: http://www.deadcellzones.com/full.html

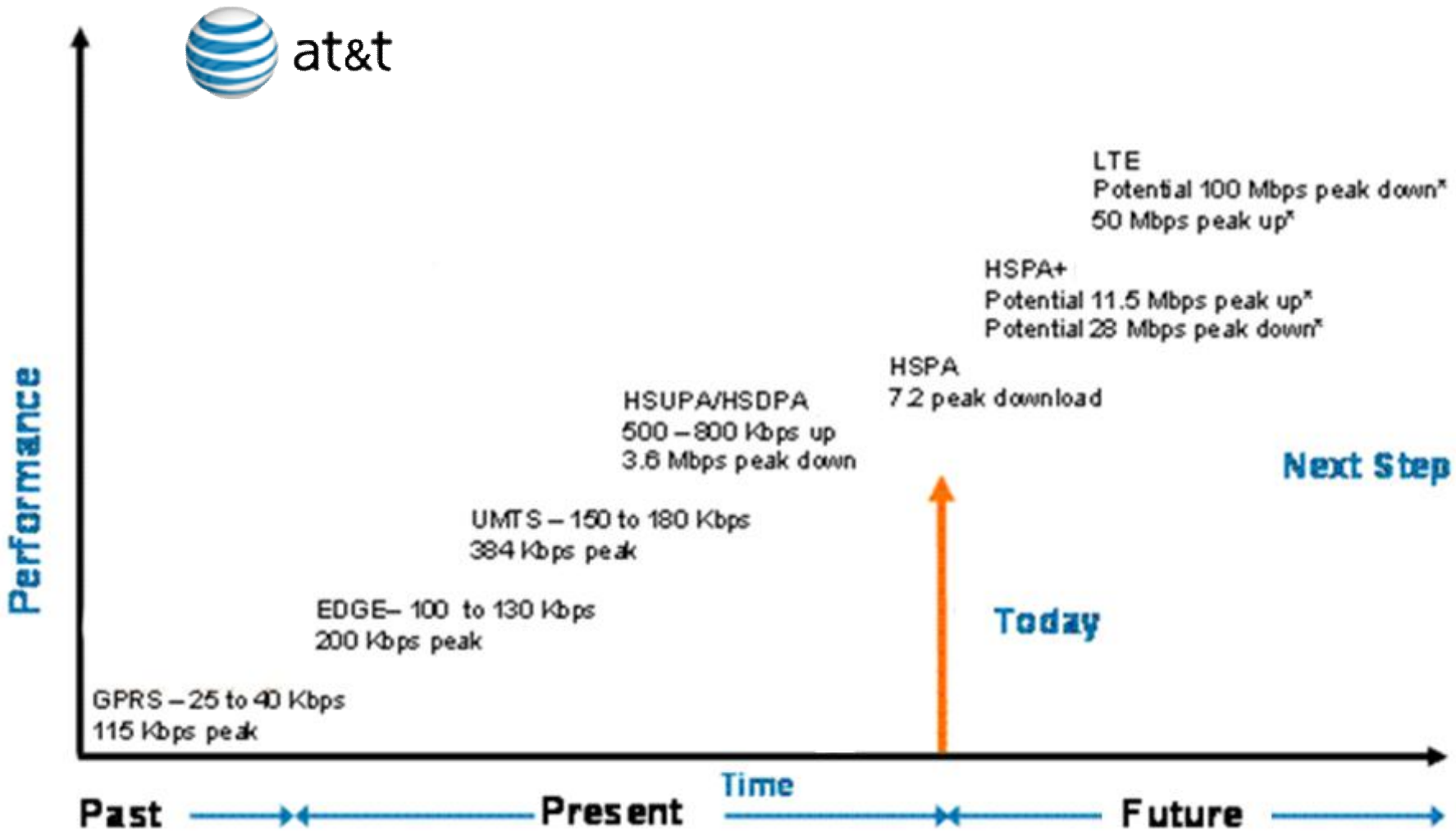
It Isn't Reliable Enough

- Network redundancy
  - Multiple towers provide overlapping coverage in many location.
- End Point Intelligence:
  - Back off re-try algorithms
  - Constant monitoring *of connectivity*
- Fixed base equipment must meet strict performance requirements:
  - Capable of 2W transmit in 850MHz band and 1W in 1900MHz band
  - Total isotropic sensitivity (TIS) at minimum -99 dBm in 850MHz and -101.5 dBM in 1900 MHz band for AT&T
- Carriers are willing to commit in service level agreements (SLA) to 98 – 99% availability
- ***Priority routing and resource allocation are coming as part of LTE***

I May Not Have Bandwidth When I Need It

- In 2G systems, Quality of Service (QoS) available for voice only, not data.
- 3G/4G systems have the ability to support QoS
  - Ability to prioritize service both data and voice
  - Carriers have not yet implement in 3G, however, bandwidth and availability remains high.
  - Different carriers will implement at generations.
  - LTE seems to be where QoS will be implemented

Bandwidth for the Smart Grid



It Is Not Secure

- A layered approach
  - All cellular carriers natively use authentication and encryption in all communications
  - At SSI, encapsulated data is further encrypted using AES 256. Additionally, each end device is authenticated.
  - Migrating to a Public Key Infrastructure (PKI)
  - All carriers segment from public IP data from private and will provide secure private pipes. *Ensure you run on a private segment!*

It Changes Too Much

- As the future is built, the past is supported
  - End point providers continually migrate to latest technology
  - Chipsets are backward compatible
    - LTE chipsets typically supports 3G
    - HSPA chipsets support EDGE and GPRS
  - Carriers today will make up to 20 year network commitments on 3G technology.
- Technology is starting to converge

It Changes Too Much

	Public Wireless Technology Family		
Generation	GSM	CDMA2000	Other
2G/2.5G	GPRS, EDGE	1xRTT	
3G/3.5G	UMTS/ HSPA(+)	EV-DO	
4G	LTE	UMB	WiMAX

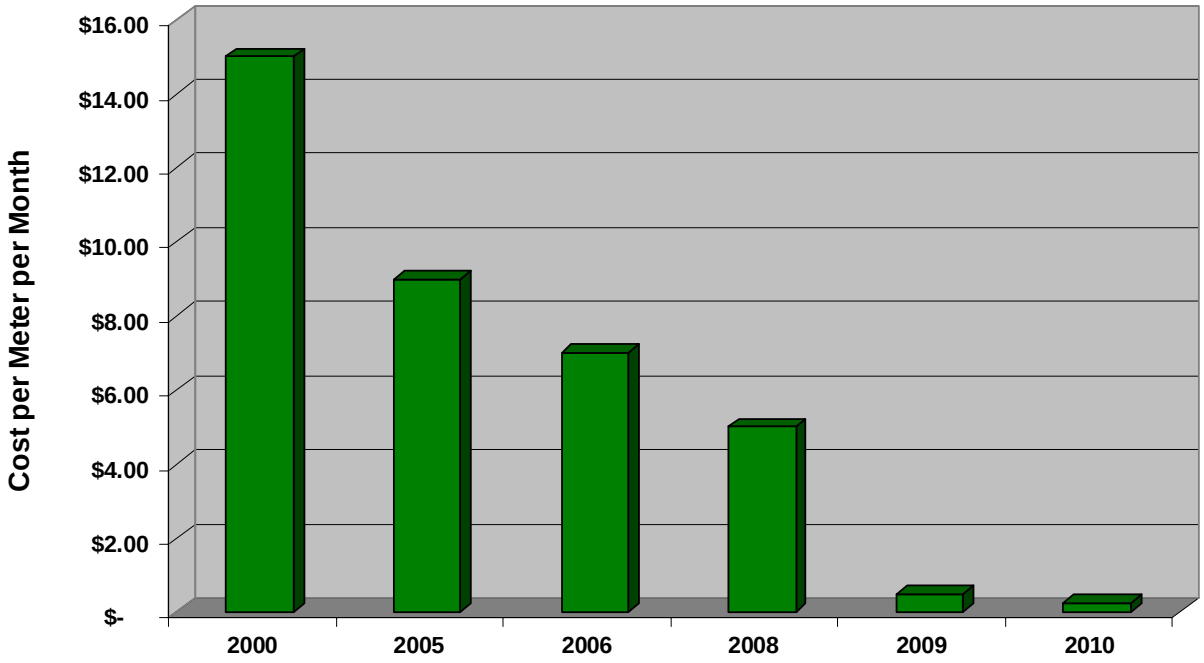
I Can Manage It Better Myself

AT&T Global NOC – New Jersey

- All Networks understand critical nature of infrastructure
  - AT&T's GNOC tracks and monitors approximately 10 petabytes of data transmitted on their global network each day.
  - Dedicated "feet on street" for system maintenance.
- Disaster Management
  - Cellular on Wheels (COW)
  - Cellular on Light Trailer (COLT)

It Cost Too Much

- 1st agreement with AT&T announced in 2009
- AT&T followed by other cellular providers
- Competitive pricing and SLAs to support system-wide deployments
- Cost now under a $1/Mbyte/month



Inside Looking Out

"Walls and bars they surround me.."

Communications with "Beyond the Meter" Devices

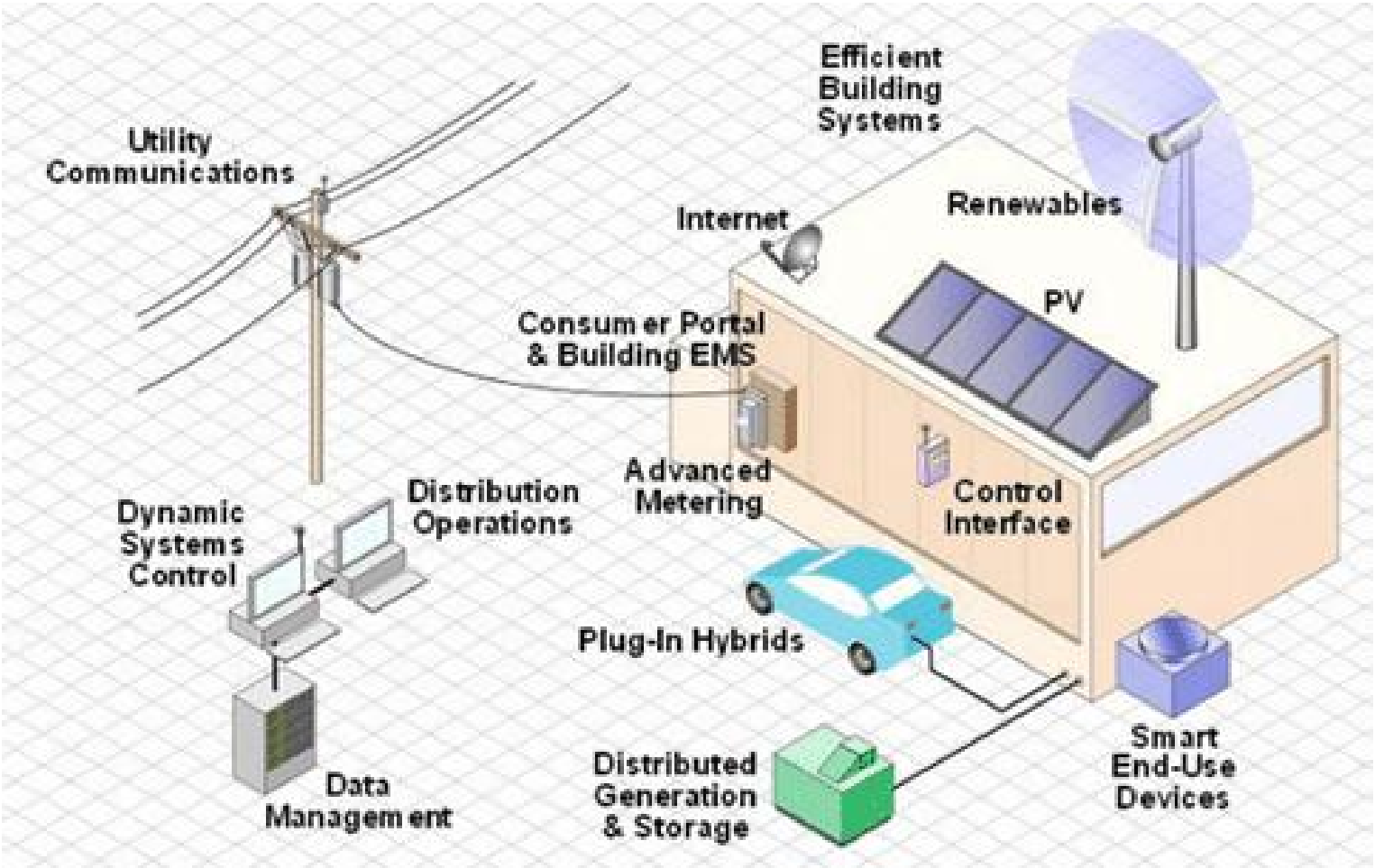


Diagram from EPRI

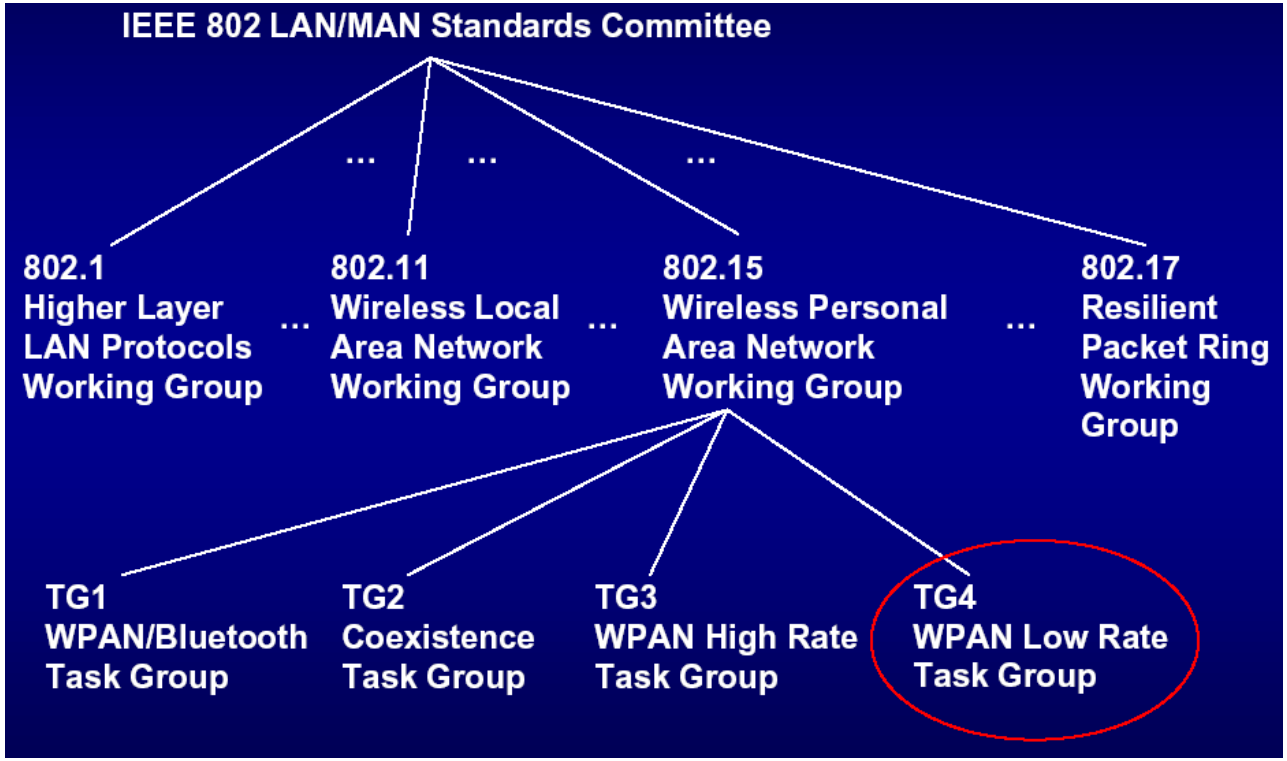
Interaction involves all intelligent electronic devices (IEDs),distributed computing elements, and communication with and between IED elements….

Open Systems Interconnection Reference Model

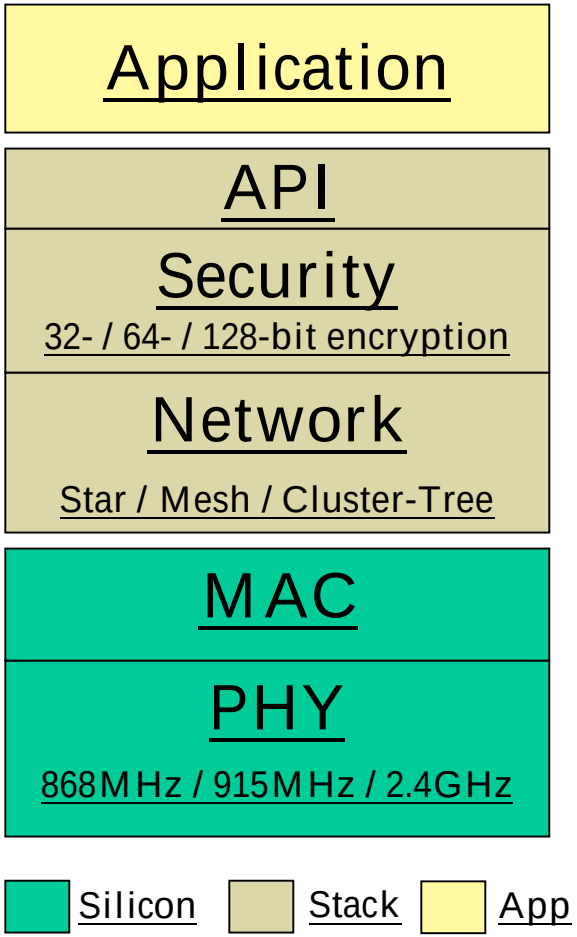
OSI Model				
	Data unit	**Layer**	**Function**	**Examples**
Host layers	Data	7. Application	Network process to application	HTTP, FTP, SMTP
		6. Presentation	Data representation and encryption	SSL
		5. Session	Interhost communication	Sockets, RTP
	Segment	4. Transport	End-to-end connections and reliability	TCP
Media layers	Packet	3. Network	Path determination and logical addressing	IP
	Frame	2. Data Link	Physical addressing	Ethernet (MAC & LLC)
	Bit	1. Physical	Media, signal and binary transmission	Ethernet (physical)

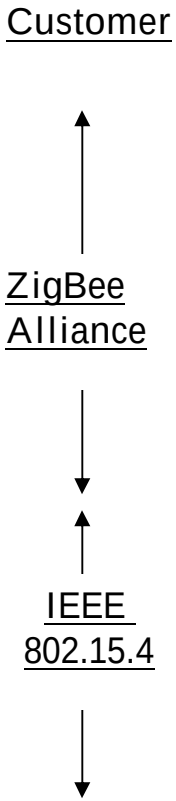
LAN/HAN Connection Flavors for MAC/PHY

- Wired
  - IEEE 802.3 Ethernet
- Wireless
  - IEEE 802.11 WiFi
  - IEEE 802.15.4 ZigBee and 6LowPAN



802.15.4 ZigBee





ZigBee Alliance

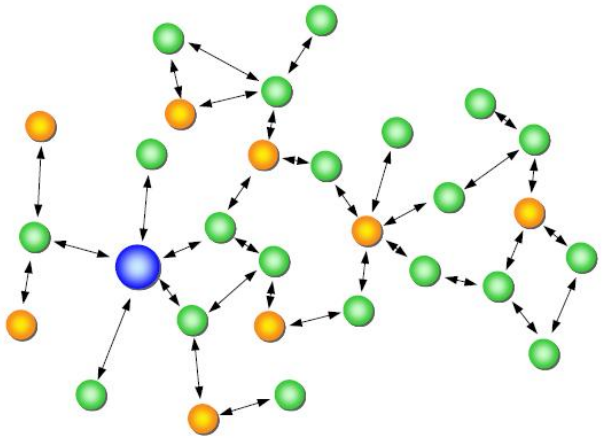
- "the software"
- Network, Security & Application layers
- Brand management

IEEE 802.15.4

- "the hardware"
- Physical & Media Access Control layers

802.15.4 ZigBee

- Three Network Topologies
  - Star
  - Cluster Tree
  - Mesh
- Network Consist of Device Types
  - Coordinator – form network
  - Routers – forward traffic
  - End devices – unable to forward traffic



Example of Ad hoc Mesh

802.15.4 ZigBee – Smart Energy Profile

- Scope & Purpose
  - Applications for two-way data communications metering and energy management devices
- SE Services
  - Energy Services Portal
    - The Energy Services Portal connects the energy supply company communication network to the metering and energy management devices within the home
  - Metering End Device
    - The Metering End Device is a meter (electricity, gas, water, heat) that is fitted with a ZigBee device
  - In-Premise Display
    - The In-Premise Display will relay energy consumption data to the user by way of a graphical or text display
  - Extension of Home and Commercial Building Automation devices for use with AMI services such demand reduction

Prediction…!

- Support for 802.15.4 is waning in the customer end device area
- Support for 802.11 WiFi is growing
- Look for:
  - WiFi connected devices most likely utilizing the Smart Energy Profile offered by ZigBee
  - Mesh meter providers to utilize 900 MHz 802.15.4 for interoperable MAC/PHY utilizing a 6LowPAN type protocol (read end to end IP with high security)

Some End Point Applications

Example: Residential AMI Infrastructure

Utility IT Infrastructure

Public Wireless WAN

Point-to-Point Network

2.4 GHz ZigBee, 6LowPAN or WiFi

Utilizes IEEE 802.15.4 MAC/PHY or IEEE 802.11

900MHz Water and Gas

Starting to migrate to IEEE 802.15.4 utilizing both 900MHz and 2.4GHz PHY

Use Case: C&I Meter Reading

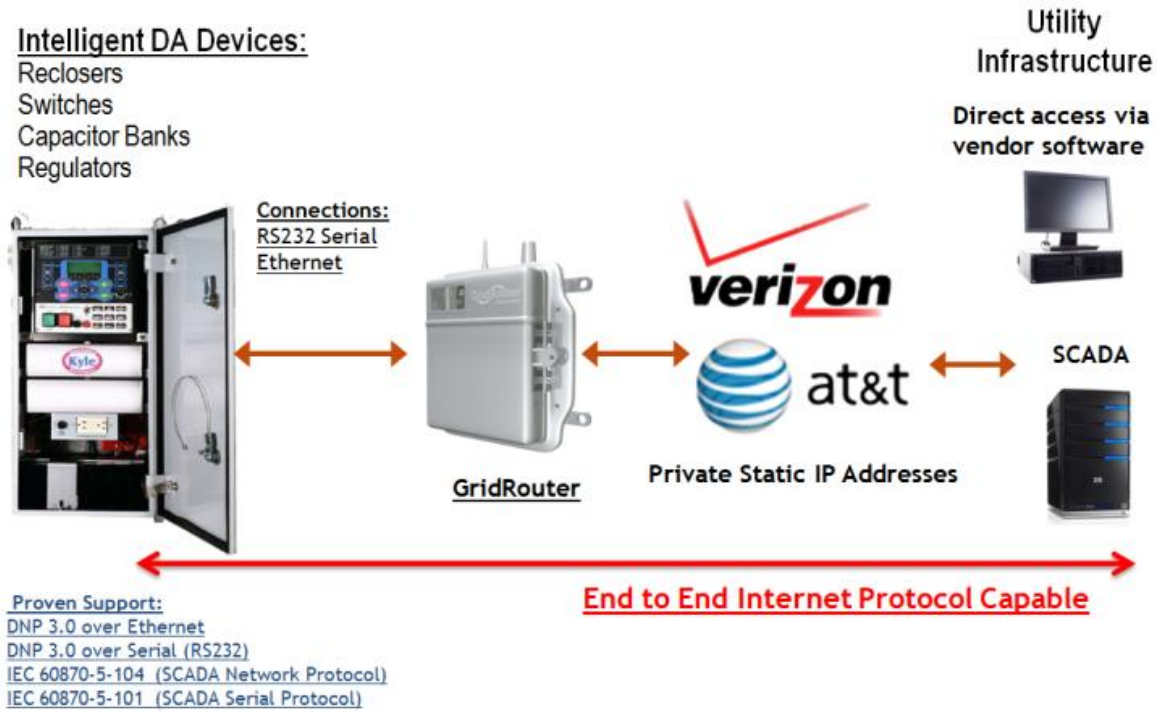
- Customers Include:
  - Duke
  - Alabama Power Company
  - Georgia Power Company
  - Consolidated Edison
- Allows access by data collection software such as MV90 as well as meter vendor software.
- Deployed in serial communications applications utilizing RS232 and RS485
- Deployed in Ethernet communications applications
- WAN connectivity by AT&T and Verizon
- Private Verizon segment
- Private AT&T APN

Unique Benefit:

• Connectivity for IP and legacy serial devices supported by a single device

Use Case: Electric Distribution

- Customers include:
  - Duke
  - CenterPoint
  - Southern Pine EPA
  - City of Winfield
- Controllers include Cooper, Schweitzer, and ABB
- Utilized in 10 second polled SCADA or in a "connect as needed" environment
- Proven in RS232 and Ethernet applications.
- Private WAN connection via Verizon and AT&T
- Ethernet allows connectivity for different services such as DNP and vendor software concurrently
- Firewall with port forwarding rules

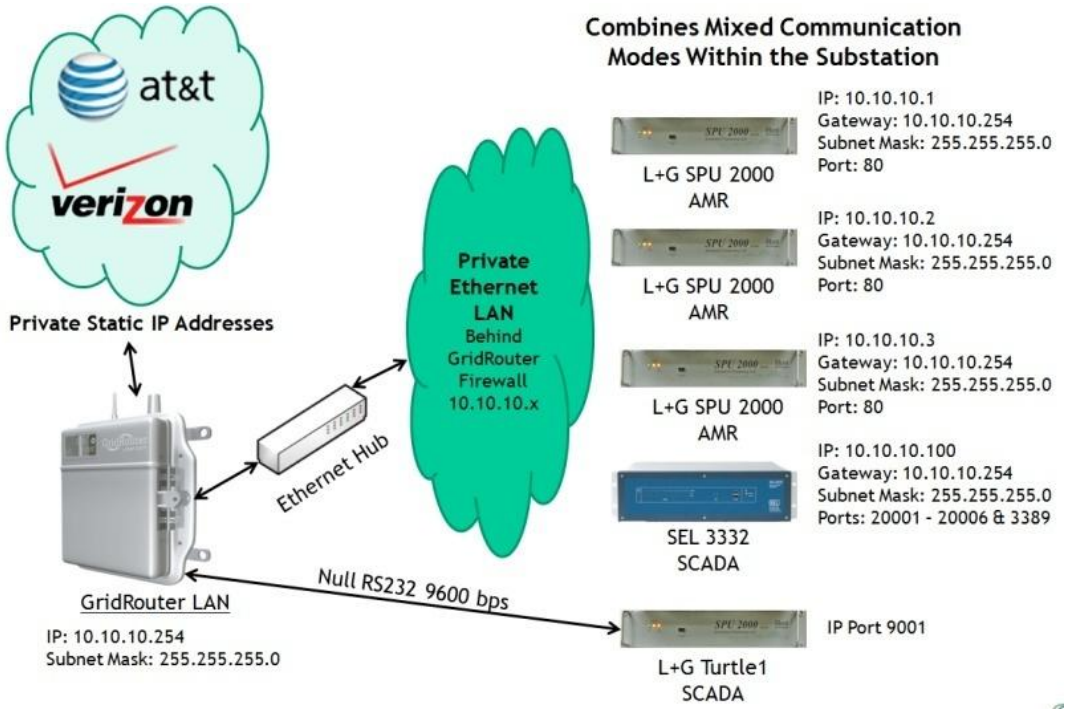


Unique Benefit:

- Instant connectivity without infrastructure build out
- Multiple head-end access to single or multiple end devices
- Serial and IP connectivity with a single device

Use Case: Distribution Substation Communications

- Central Texas Electric Cooperative
  - AT&T private APN provides unique WAN IP address for each substation
  - LAN architecture – LAN IP addressess and ports are the same at each substation
  - Supports 10 second SCADA polling
  - Supports legacy AMR
    - Serial and Ethernet
- City of Oxford
  - AT&T WAN
  - Connectivity to SEL-3530 RTAC
  - 10 second SCADA data for all substation elements
- Grayson-Collin Electric Cooperative
  - Verizon EVDO WAN
  - Cooper ProView access via fiber Ethernet to six Form 6 reclosers
  - Access for streaming video surveillance



Unique Benefit:

- Simplified LAN communications architecture
- Connectivity for IP and legacy serial devices supported by a single device
- Multiple head-end access to multiple end devices

Summary

- The Smart Grid “End in Mind” is to operate a closed loop system where the customer is an integral part of the loop.
- There are a variety of communications media that can be utilized to connect the “loop”
- Cellular communications are viable for many utility uses
- While expecting further connectivity to “in-home” devices by utilities, standards are far from set.

For additional information contact:

R. Bryan Seal, P.E.
601-917-3980
bseal@smartsynch.com