Role of WiFi / IEEE 802.11n & Related Protocols in Smart Grid

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Goals.

The Smart Grid…

•Enable active consumer participation in electricity consumption, controlling user and producer costs and shaping/reducing energy demand

•Make the grid better able to integrate new power sources (wind, solar) that are numerous intermittent and difficult to forecast

•Prepare for large load fluctuations due to rooftop solar and charging electric cars at home

•Increase grid reliability & efficiency (with full security)

A robust, secure communications infrastructure is essential to the smart grid

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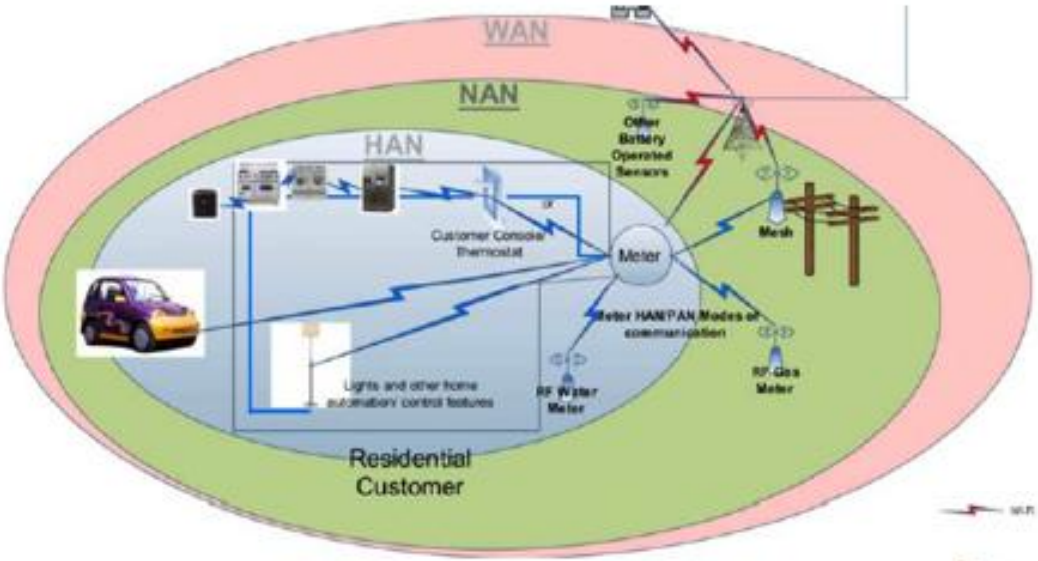
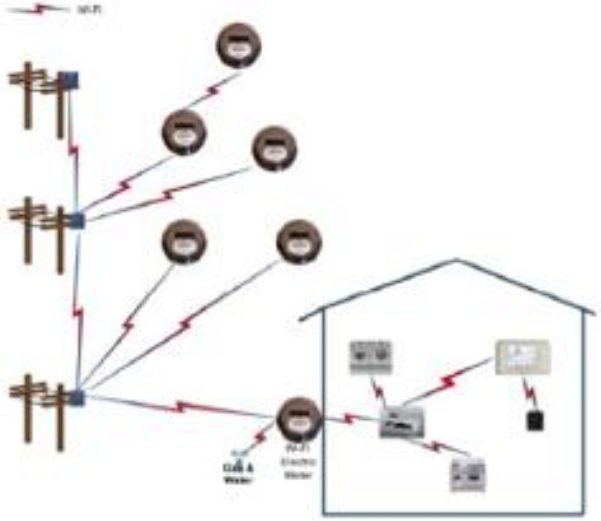
Smart Grid Networks



Three Smart Grid Segments

The Home Area Network



The Smart Grid Neighborhood Area Network

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Smart Grid Networks.

Home Area Network

- Communication between appliances and sensors in the home, with consumer remote access and possibly Utility access and control of major electrical loads

Advanced Metering Infrastructure

- Meters that report regularly to the Utility and can be a gateway to the HAN for pricing information and control

Electricity Grid Sensing and Control

- A network for real-time monitoring and control of transmission and local distribution networks

The smart grid will use several complementary PHY/MAC standards

Home Area Network Requirements

•Distances < 100 ft

•Variable RF propagation conditions: e.g. concrete walls and RF-reflecting surfaces

•Potential standards: Zigbee, Wi-Fi, Homeplug

•Cost & power characteristics suitable for incorporating into appliances & battery-powered devices

•Bandwidth requirements for smart grid applications are low (kbps), but if integrated with data networking, Internet, video and TV become high (50+ Mbps throughput)

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HAN.

Roles Of ZigBee And 802.11n In HAN

ZigBee

•Designed for low bit-rate, low power draw, simple, low cost silicon

•Short-range and limited in rates

•For building automation, networked light switches, thermostats etc, ZigBee still has an advantage in power efficiency

•Control infrastructure for STBs and remotes, interconnect other ZB devices via RF4CE

802.11n

•Much higher complexity, but higher rates, volume silicon cost is lower now

•Long-range measured over 3-7 wall penetration

•For home multi-media delivery and HD video distribution

•Mobile SIP/Telephony an alternative to DECT or legacy cordless telephone systems

Smart Energy 2.0, the next-generation energy management protocol for Smart Grid-enabled homes would require ZigBee and 802.11n to inter-operate

Wi-Fi in the Home Area Network

•Wi-Fi with 802.11n is _close_ to satisfying all requirements:

- Range to 100ft+ _reliably_ indoors, with MIMO

- Inexpensive silicon through mass production

- Low power consumption

- High bandwidth thanks to 20/40MHz channels and MIMO (to 450Mbps with 3x spatial streams)

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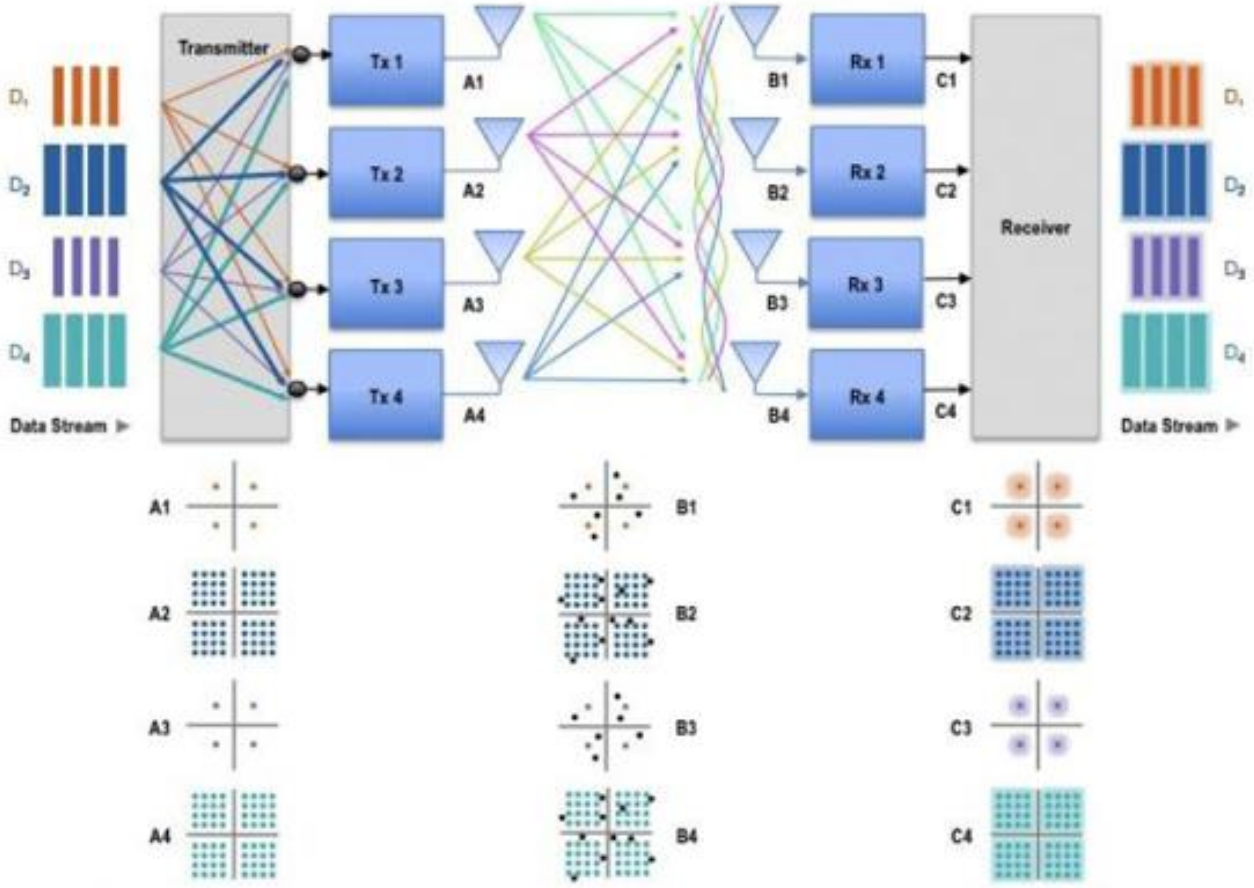
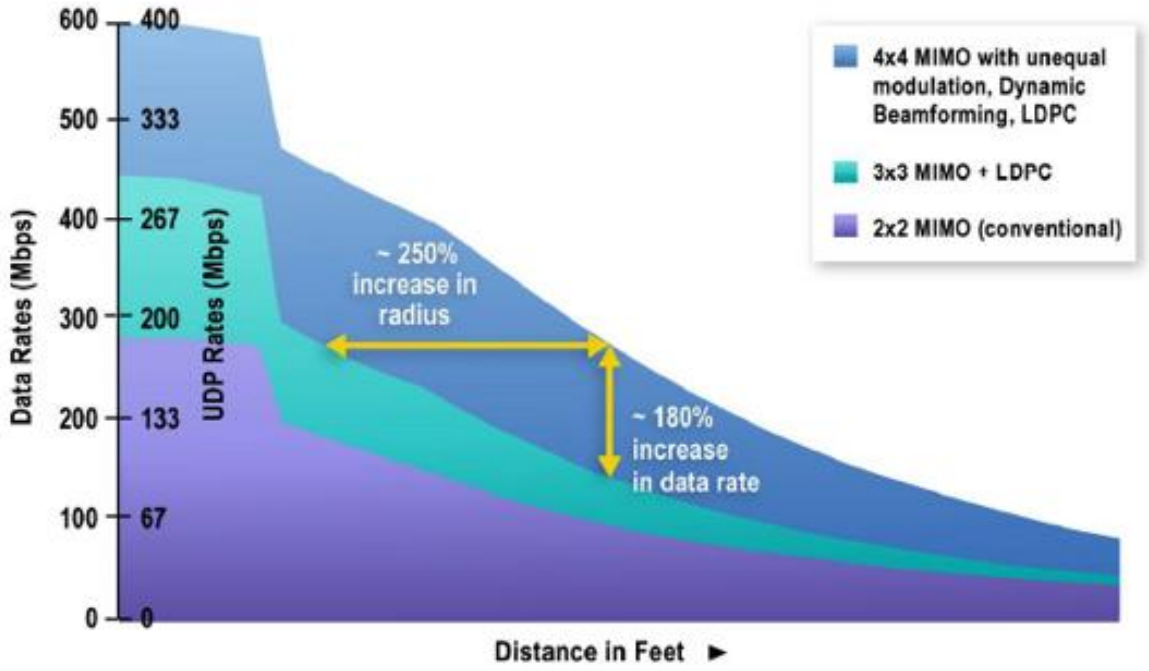
4X4 Systems.

Wireless 4X4 Equivalent to Wired Networks in Performance

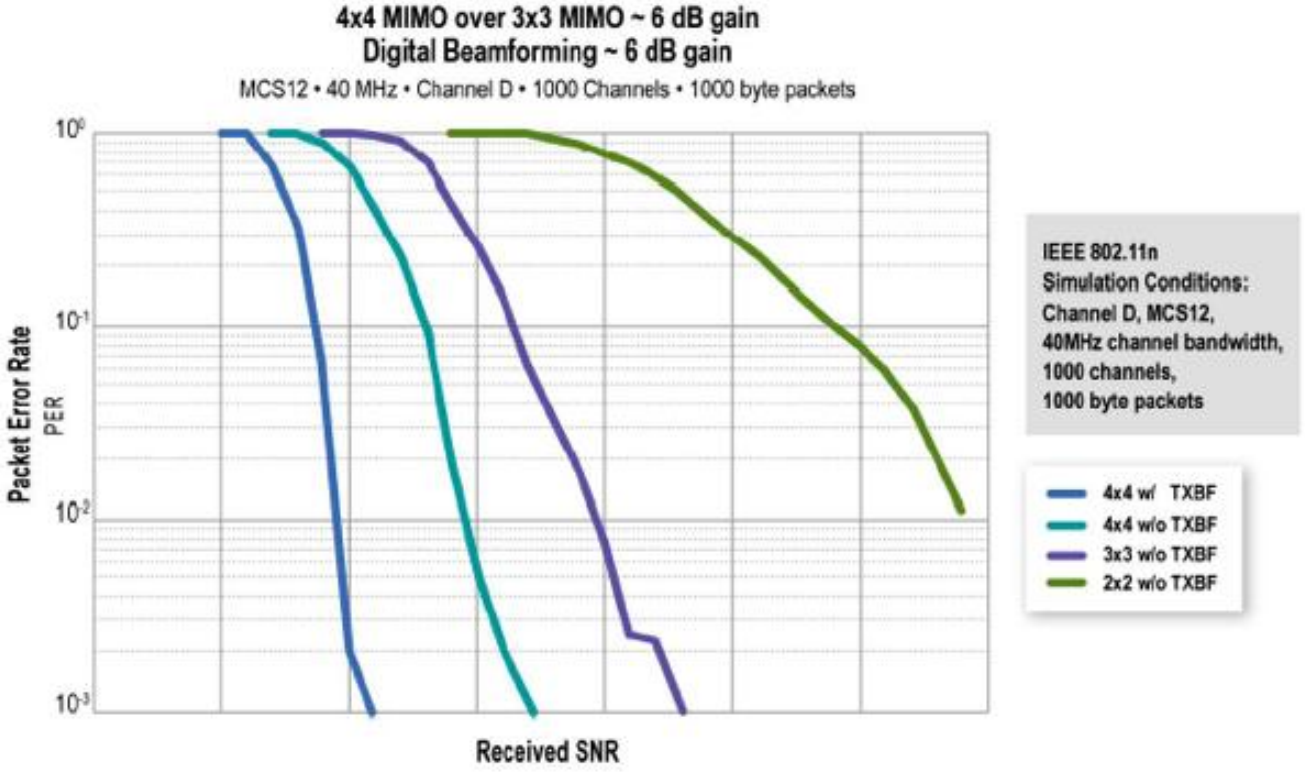


Higher Throughput and Wall Penetration in 4x4 Systems



• *Typical simulation graph used to show over-the-air bitrate. PER is set to about 1%, and packet retransmission is needed to achieve desired reliability at the expense of delay. In this model, at a distance of 50 feet, the 4x4 system's throughput outperforms that of a 3x3 system by about 180%.*

Lower PER of 4X4 MIMO



- *nxn MIMO Packet Error rate for various IEEE 802.11n systems. 4x4 MIMO with Adaptive Beamforming has 12 dB advantage over 3x3 MIMO without Beamforming.*

4X4 Systems.

Dead Zones and Poor Coverage in Wi-Fi Home Networks

- Integrate the latest 4x4 802.11n beam forming technology with IP layer QoS
- Enable robust indoor mesh networking for HD video distribution
- IP multicast flow router

Automated Meter Infrastructure Requirements

- Low capital and operational cost
- Easy installation, with minimal custom engineering
- High reliability & security
- Flexibility over distance (20m – 1+km between buildings)
- Low bandwidth requirements (kbps)

Wireless Mesh in the AMI Network

- Several AMI vendors incorporate wireless:
  - Wi-Fi (inexpensive, unlicensed, short-range)
  - WiMAX (licensed, longer-range)
  - Cellular data (carrier subscription service, near-ubiquitous)

- Wi-Fi is very low-cost equipment (volume silicon) and has no licensing or subscription costs

- Wi-Fi can be built as a self-organizing mesh, incorporating pt-pt links and omni antennas

Mesh Networking in NAN

- Dynamic recognition of peers
- Packet and flow classification
- IPV4 and IPV6 flow routers

Transmission & Distribution: Monitoring and Control

•Current SCADA networks do not sense/control with the required speed, or reach to the edges of the distribution network

•A new communications infrastructure is required, with orders of magnitude more bandwidth and endpoints.

•The sensing/control network for transmission & distribution must be extremely robust and secure

Wi-Fi in the Distribution Network

•Wireless rather than wired communications is ideal around high-voltage power lines as it is electrically isolated

•Wi-Fi equipment is low-power and can be solar/battery powered, providing resilience during grid disruptions

•Self-organizing mesh networks incorporate short- and long-distance links and advanced security protocols

•Applications such as surveillance cameras are already integrated into Wi-Fi mesh networks

Applications for the Smart Grid

- PTZ Camera attached to 802.11n edge Mesh node
- 8db antenna provides wireless connectivity at 700 feet from mesh node
- Ideal for disaster recovery networks, rapid deployment

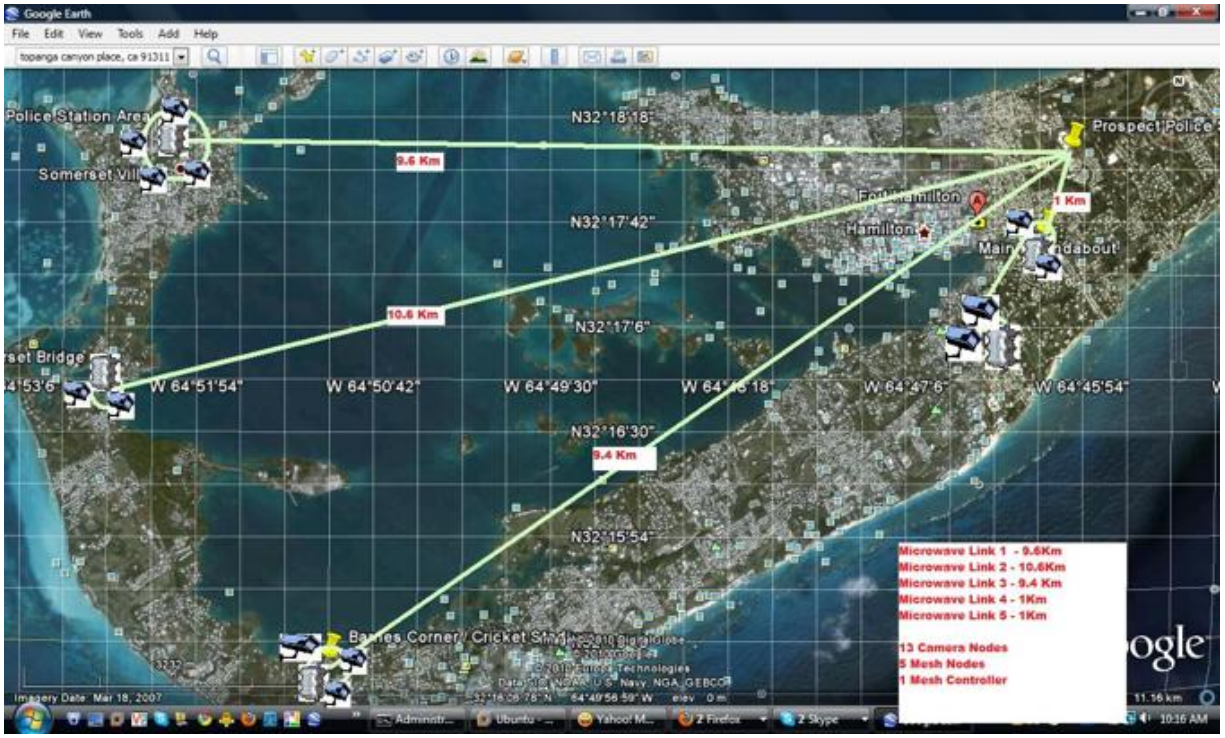
Applications for the Smart Grid

- 80W solar panel

- 10A charge controller

- Total power requirement for the mesh node is 20W

Applications for the Smart Grid: City Wide Video Surveillance



Hamilton, Bermuda

- 5 Mesh Networks
- Interconnected over Microwave
- 10km longest path
- Police video surveillance
- 802.11n Mesh nodes for camera traffic

Applications for the Smart Grid: Remote Mining Sites

El Brocal, Peru

-Open Mine

-Altitude 5000m

- Mining Pit
  - 3 km wide
  - 0.5 km deep

-Satellite BH

- Mobile Mesh on CAT Trucks

- 802.11n Mesh nodes for Comm.

Conclusions:

- The smart grid is built on communications networks
- Several protocols and standards will be used
- Wi-Fi is well-established, with known cost, power, bandwidth and range envelopes
- Self-organizing Wi-Fi mesh networks will be a part of the Home Area Network, Advanced Metering Infrastructure and Transmission/Distribution monitoring and control networks
- TV White space availability on the horizon is promising