802.16/802.24 Tutorial: Proposed 802.16s Narrowband Project

Roger Marks
IEEE 802.16 WG Chair
# Agenda

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802.16/802.24 Tutorial: Proposed 802.16s Narrowband Project

802.24 Vertical Applications TAG - applications of 802.16 in utility field area networks

Tim Godfrey (EPRI)
IEEE 802.24 TAG Chair
Agenda

• What is a Field Area Network (FAN)?

• Why would a utility use 802.16? Why not LTE?

• What are spectrum options for FAN?

• Why amend 802.16?
Utility Deployed FAN – private network

- Simplified chart – many other factors must be considered
Popular 802.16 products for utilities

- GE MDS Mercury
- Siemens RUGGEDCOM WIN7200
- Full Spectrum FullMAX
- Cisco Connected Grid Router (Station Only)
- Airspan AirSynergy 4G
LTE Network Architecture

- Fully integrated with legacy mobile system
- Oriented towards mobile network operators needs
802.16 Network Architecture

- Simpler architecture with L2 support
- More aligned with utility IT services and architecture
Other key differences in 4G technologies

- **Spectrum Type**
  - LTE typically uses FDD (paired) spectrum,
    - TD-LTE standard does support unpaired
    - Most equipment is for FDD
  - WiMAX typically operates in unpaired spectrum
    - Best match to “uplink biased” grid applications

- **IEEE 802 Ethernet Model**
  - Intrinsic support for Layer 2 connectivity
  - IEEE 802.16 supports an Ethernet Interface and Layer-2 messages (e.g. IEC 61850 GOOSE)
  - LTE is IP (layer 3) only – Layer 2 must be tunneled

- **Local forwarding**
  - 802.16 supports direct SS to SS forwarding through base station
  - LTE typically routes all packets through EPC
    - Local gateways have been proposed
Why not Cellular IoT or other commercial wireless?

**Public**
- Low CapEx, ongoing OpEx
- Security and reliability up to carrier
- Carrier provides the spectrum
- Network evolution up to carrier
- Network maint & repair up to carrier

**Private**
- High CapEx, lower OpEx
- Utility controls security and reliability
- Utility provides the spectrum
- Utility controls pace of evolution
- Utility controls maint & repair

- Utilities that choose the private option have specific financial and operational reasons, and are unlikely to change to a public provider.
- They are not potential customer for operators
Spectrum for utility 802.16 FANs

- 5.8 GHz Unlicensed
  - WiMAX certification and profiles
  - Less attractive due to poor propagation at high frequency
- 4.9 GHz Public Safety
  - WiMAX certification and profiles
  - Limited availability of spectrum – negotiation with PS entities required.
- 3.65 GHz “Lightly Licensed”
  - WiMAX certification and profiles
  - Has been widely used by over 100 utilities.
  - Recent rules changes have made the band less attractive for future expansion
  - Reports of interference in utility pilots
- 1.8 GHz Canadian band
  - WiMAX certification and profiles
  - Widely used Canadian utilities.
- 700 MHz Upper A Block
  - Superior propagation
  - Too narrow to support 802.16 or LTE as currently specified
Why narrow channel is of interest

- Spectrum is less attractive to mobile operators since LTE is not supported
  - Cost is moderated
- Narrow spectrum means lower data rate, but capacity is still sufficient for grid applications
- Other spectrum with similar narrow channel characteristics is available or may become available:
  - 217 MHz, 406 MHz, 901 MHz, 1.4 GHz
Conclusion

• 802.16 is technically well suited for utility Field Area Networks
• 802.16 continues to be widely used for utility Field Area Networks
• The industry desires to use 802.16 for 700 MHz and in other narrow allocations, but a standard is needed
Introduction to UTC

• Established in 1948, UTC advocates for the telecom and IT interests of electric, gas and water utilities and other critical infrastructure industries.

• Based in Washington, DC, UTC has affiliate organizations around the world in Europe, Canada, and South America.

• Spectrum access is a key issue for utilities, as utility modernization places new demands on the underlying communications infrastructure.
Overview

• Issue: Spectrum Access
  – Assessment
  – Options
  – Risks
  – Strategic Approach
Utility Spectrum Access: Assessment

• Utilities need access to additional spectrum that is suitable to meet their increasing communications requirements from smart grid and other applications.

• Issues:
  – How much?
  – What frequency range?
  – When (current and future)?

• Next steps: Need to develop a technical basis and industry consensus for access to a band or bands that will meet utility functional requirements for a variety of applications and topologies.
Spectrum Access: Options

• UTC Whitepaper on Smart Grid Traffic Estimate:
  – Identifies bandwidth requirements for individual smart grid applications and aggregates them based on different use cases, including electric transmission and distribution networks, as well as gas networks.
  – Estimates bandwidth requirements on a site-by-site basis for different abstract communications networks at 450 MHz, 700 MHz, and 1.8 GHz.
  – Total bandwidth requirements are approximately 6-8 MHz, which may be higher or lower depending on the frequency range of the network.

• EPRI Assessment of Licensed Communication Spectrum for Electric Utility Applications:
  – Identifies 406-420 MHz as “particularly attractive” due to compatibility with LTE standard and low demand for this spectrum for commercial communications.
  – Secondary market spectrum; 700 MHz also possible options.
Spectrum Access: Risks

• Cost of spectrum access
  – Purchasing spectrum on the secondary market
  – Relocating incumbent operations
  – Equipment availability

• Competition from commercial carriers
  – Federal regulators under intense pressure to allocate additional spectrum for broadband commercial services.
  – Carriers want utility business.

• Spectrum scarcity
  – Suitable spectrum is difficult to find, especially under 2 GHz and especially on a dedicated basis.
  – Unlicensed spectrum available, but subject to congestion/interference
Spectrum Access: Strategic Approach

• Coordinated/Unified support across all utilities and all critical infrastructure sectors.
  – Engage with energy and water regulatory agencies to raise awareness and develop support.

• Develop a quantified substantiated basis for spectrum access
  – “We want spectrum!” won’t work. Must be specific and targeted.

• Elevate this initiative worldwide
  – Develops economies of scale, which attracts investment and equipment development/lower costs.

• Standardization
  – Develop solutions that are standardized, rather than proprietary to promote interoperability and avoid stranded investment.
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Utility Perspective on Standardization for Narrow Channel Operation

Kathy Shaft P.E.
Senior Telecommunications Engineer
Who is Great River Energy?

- G&T Cooperative
- 28 member owners
- 12 power plants
- 4700 miles transmission lines
- 2\textsuperscript{nd} largest supplier in MN
Importance of Narrow Channel standard for Utilities

- More utilities using the same standard and technology
  - Bigger market for vendors
  - More vendor choices
  - More stability
GRE's current SCADA Network

- Uses 700 MHz A band
- Communicates to 500 substations:
  - Long path lengths
  - 3 Sector (narrow channels)
  - Frequency Reuse
  - Throughput (1100/250 kbps)
- Applications:
  - SCADA (critical)
  - Metering
  - Remote Access
- Backhaul Coop data
  - AMI/AMR
  - Load Control
- Distributed generation
Current SCADA Network Cont.

- Modified DOCSIS 2.0 cable modem standard (proprietary)
- Three years after deployment the vendor went out of business
- Even with access to the IP we were too small for a vendor to make equipment for us
- Self maintaining now but equipment is aging and we have limited spares
What Does the Narrow Channel Standard do for Utilities?

- Most spectrum options available to utilities are 1MHz or smaller (this forces us to use proprietary solutions)
- This potential solution provides us with more stability
- More vendor and equipment choices
- Utilities have started purchasing licenses in the 700 band
- If there was a standard its likely more would join
Importance of Private Utility Networks

- We use our networks for critical SCADA traffic
- Command and control of the electric grid
- We cannot rely on public networks for our critical SCADA data
Questions?
Field Voice and Data Communications System

Project Objectives:

- Replace PGE’s 150 MHz Field Voice Communications System (FVCS)
- Develop a Field Data Communications System (FDCS) to allow for mobile data communications and system automation
- Purchase spectrum to replace current shared use radio channels with PGE exclusive radio channels

Importance of this Project:
This project is strategic to PGE’s operations. Foundational to this project is PGE owned radio spectrum

Board approval:

- **February 2015**: Approved $X million for purchase of spectrum, business requirements, initial design and legal fees
- **February 2016**: Will request up to $Y million in project funding based upon engineering design

Sponsor:
Larry Bekkedahl

Team:
Dale Clark; Mike Wagner; Sal Faruqui
Current Field Voice Communications and it’s limitations

- T&D system users:
  - Line Crews
  - Substation Crews
  - Meter Services
  - Field Connect Reps
  - Field Engineers
  - Corp Security
- Generation sites have their own land mobile radio systems
- No coverage for transmission lines outside distribution territory
- Inability to communicate between regions
- Single conversation at a time per region
- No coverage in certain non-urban service territory and transmission areas causing safety, reliability and efficiency issues
- Does not support consolidation of all regions into a single integrated service network
- Experiences interference from other frequencies
- Outdated equipment

Distribution Regions
Transmission lines

Current coverage
Generation plants
Future Field Voice Communications System

Recommendation:
Design, build and commission a land mobile radio system based on 220 MHz spectrum.

Benefits:
- Seamless wide-area coverage for distribution, transmission, generation and corporate operations.
- Highly reliable, exclusive private use, multi-party two-way communications voice network to ensure employee safety, system reliability and efficiency.
- Scalable platform to meet future operations.
- Resilient communications network to support business continuity and emergency management.
- Modern equipment; lower operating and maintenance cost.
- Centralized network management.

“Regionless” Distribution
Largest possible coverage
Transmission lines
Generation plants
Spectrum purchased by county

Spectrum purchased by county
Spectrum Usage

**700 MHz Conceptual Spectrum Allocation**

Data = 650 kHz/base station supporting approx 512 kbps

**Integrated Grid Apps:**
- SCADA
- Distribution automation
- Machine to machine – protective relaying; cap banks, etc.
- Conservation Voltage Regulation (CVR)
- Demand management
- Mobile Workforce

Uplink (Mobile-to-Base)

Data

Voice

Digital Mobile

Radio

Guard Band

Data

Voice

Digital Mobile

Radio

Guard Band

Data

Guard Band

Uplink (Mobile-to-Base)

Downlink (Base-to-Mobile)
Schedule and Roles and Responsibilities

2015
- Q4
  - Needs Assessment
  - Radio System Replacement Plan
  - DMR System Procurement Support
  - Federal Engineering

2016
- Q1
  - Update to Board
- Q2
  - Equipment Vendor selected
- Q3
  - System Design by Vendor
- Q4
  - System implementation & Testing
  - User training
  - Equipment Vendor
  - Review System Design
  - Network Design
  - Oversee Site Engineering, Implementation, Testing & Debugging
  - DMR3 testing
  - Product testing

2017
- Q1
- Q2
- Q3
- Q4

First usage of system

We are here
PRIVATE LICENSED SPECTRUM FOR UTILITIES
UPPER 700 MHZ A BLOCK SPECTRUM

- Alternative Spectrum Sources for Utilities
- Private Licensed Spectrum Advantages
- Upper 700 MHz A Block Specifics

Robert Finch
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For the Mid 21\textsuperscript{st} Century Utility (and Much Sooner) – \textit{Spectrum is Mandatory}

- Fast effective communications, monitoring and control between all sources, transmission and distribution equipment and users of electricity (or gas, water, etc.)
- Wireless to replace \textit{wired TDM and leased line circuits being cancelled by telcos}
- Bandwidth and latency to match requirements
- High security and reliability
- \textit{Typically funded by operating savings \& increased reliability}
- Supports AMI, distributed generation and storage, demand response and various regulatory and competitive structures
- Happier customers + increased profits

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Potential Spectrum Sources Under Consideration

1. Unlicensed (and Lightly Licensed)
2. Shared Access
3. FirstNet LTE System - share excess capacity from conceptual system
4. Shared or exclusive licensed spectrum grant from government
5. Purchase Exclusive Licensed Spectrum
Spectrum Alternatives - Summary

- Unlicensed – Power limits and increasing interference problems
- Authorized Shared Access – Uncertainty, power limits, complexity and dominance by wireless carriers
- FirstNet = Second class customer of dysfunctional partner with no network yet
- Grant of spectrum from government? Past failures, regulator statements and possibly federal law say success is highly unlikely
- Licensed Spectrum – Investment in the future
Obtain Licensed Spectrum

- Except for narrowband in limited situations, will require purchase or lease
- Accommodate current and future applications – Field Area Network
- High security and reliability
- Higher power levels and protection from RF interference
- Operating savings and reliability improvements justify investment
Questions Before Spectrum Purchase

- How much (bandwidth) is available, and is that enough for the application(s)?
- Will the propagation characteristics and power be adequate?
- Are there any legal disputes among licensee partners or between licensee and FCC or adjacent licensees?
- Have prior transfers of similar licenses been approved?
- When does current license period end, and what is required for renewal?
- Does planned use match license rules? Waiver required?
- Are there any other license operations in the same band in your area of operations?
- What ecosystem of users and vendors exists in the band?
Upper 700 MHz A Block

- Exclusive 2 x 1 MHz licenses, located between Verizon and FirstNet with same interference protection rules
- Fixed or Mobile
- Best combination of propagation and capacity for utility use
- Recommended by UTC in 2013 White Paper

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700 MHz A Block Licenses
Held by Selling Investors and Utilities Nationwide
Technical Aspects – Upper 700 MHz
A Block “Wideband”

- Transmit power:
  - Up to 1000 Watts ERP at 1000 feet at 757-758 MHz
  - Up to 30 Watts ERP at 787-788 MHz
- Superior propagation over terrain and through foliage
- Fixed or Mobile – Pt-Pt or Pt-Multipoint
- FDD or TDD
- Capacity estimate: 4 Mbps per tower site
- Equal interference protection with adjacent bands – OOBE attenuation ≥ \( 43 + 10 \log P \) dB
- Most available bandwidth in private band < 1 GHz
Utilities Using and Acquiring Upper 700 MHz A Block Licenses

- System deployed: **Great River Energy** in Minnesota – Now leading “Utility User Group” including license holders and interested utilities
- **Salt River Project** – successful field trial led SRP to purchase license covering Phoenix and much of Arizona
- **Northwest Energy** acquired licenses in Montana and South Dakota
- **Portland General Electric** acquired licenses in Oregon, Washington and California Counties
- Other negotiations underway
Equipment & Standards - Upper 700 MHz A Block

- Currently available:
  - Full Spectrum
  - ConVergence Technologies
  - 4RF
- Walker & Associates supporting development and distribution of equipment
- Other manufacturers have agreed to modify equipment for band (GE Digital Energy, MiMOMax & XetaWave)
- Additional manufacturers will build to order
- Utilities are demanding standards-based equipment, and standards will expand the market

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Approaches for Narrower Channel Implementation

Guy Simpson, COO

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January 2016

www.fullspectrumnet.com
Company founded in 2006
- Privately held, Delaware Corporation
- Headquartered in Sunnyvale, CA

Target Market: Private Wireless Data Networks
- SCADA, AMI Backhaul
- Distribution Automation
- Distributed Generation
- Mobile Data

Domestic US Utility Activity
- Numerous field trials starting in Q4 2010
- First deployment Q2 2012
- Focus on rural applications and challenging terrain
Market Requirements

- Private Wireless Networks
  - Large Cells (25+ mile radius)
  - Relatively Low Endpoint Density
  - Leverage Existing Infrastructure

- Limited Spectrum Availability
  - 1 MHz channels or smaller - “Mid-band”

- Multi-megabit Throughput
  - Reverse Asymmetrical, Symmetrical & Asymmetrical

- Flexible Bandwidth Deployment
FullMAX™ - Overview

Software Defined Radio
- Frequencies from 40 MHz to 958 MHz
- Channels sizes from 200 KHz to 5 MHz
- Transmit power (Base Station & Remote) up to 20W
- Receiver sensitivity as low as -107 dBm (500 kHz channel)

Proprietary Variant of IEEE 802.16
- Time Division Duplexing
- Adaptive Modulation and Coding
- Band-AMC Sub-channelization
  - Frequency reuse factor up to 6 in single channel
- Quality of Service
  - Classification and prioritization
  - Multiple scheduling types (UGS, ErtPS, rtPS, nrtPS & BE)
Design Considerations

- **Fragmented Spectrum Availability**
  - Flexibility to support multiple FCC regulations

- **Narrower Channel Advantages**
  - Extended Range
  - Improved CINR
  - Reduced Infrastructure Costs

- **Reverse Asymmetrical Applications**
  - Balancing Uplink & Downlink Link Budgets
  - Remote transmit power similar to Base Station
  - TDD to support appropriate Downlink : Uplink ratio

- **Relatively Small Private Networks**
  - Simplified and Distributed Provisioning
Based on the 128 FFT flavor for 1.25 MHz channel

Alternate Proposals for a narrower channel...

- Reduce subcarrier spacing:
  - Signal structure is maintained with appropriate modifications of the sampling clock, the symbol duration and the TDD frame structure.

- Eliminate one or more sub-channels:
  - Typically maintain a minimum of 3 sub-channels for re-use
  - Use continuous subcarrier allocation (Band-AMC 2x3 & 1x6)
  - Modify Subcarriers used for Downlink preamble and Uplink CDMA codes so as not to extend beyond channel boundary

Single zone Band-AMC in both Downlink and Uplink
Preamble Changes
• Support no preamble configuration
• Support minimal preamble boosting (e.g. 3 dB)
• Change preamble format to exist within subcarriers used

Support New Symbol rates…
• Sampling Clock for 1 MHz wide channel : 1.12 MHz
• Sampling Clock for 500 KHz wide channel : 0.56 MHz

Support New Frame Durations…
• 12.5 and 25 ms

Support Any Number of Symbols in Any DL:UL Ratio
Support Variable Gap Duration to Accommodate Range
Proposed Changes to Improve Bandwidth Efficiency

- **Overhead Reduction**
  - DL-MAP customization…
    - MAP CRC reduced from 32 to 8 bits
    - Non-rectangular DL bursts to reduce wastage
    - Packing of SDUs belonging to different service flows
  - UL-MAP customization. Example
    - MAP CRC reduced from 32 to 8 bits

- **Automatic PHS**
  - Limited PDU header variation facilitates suppression

- **TCP Acceleration through Ack Prioritization**
IEEE 802.16s Amendment

- Market Demand for Public Standard
- Vendor Diversity and Interoperability
- Numerous Small Private Networks
- Security and Sustainability