Analysis of the 1800 MHz Band for Prospective Smart Grid Applications

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Introduction

The potential use of the 1800 - 1830 MHz band is being explored for possible Smart Grid applications. The options are essentially sharing with current occupants or transitioning current occupants to another band in order to establish a greenfield environment.

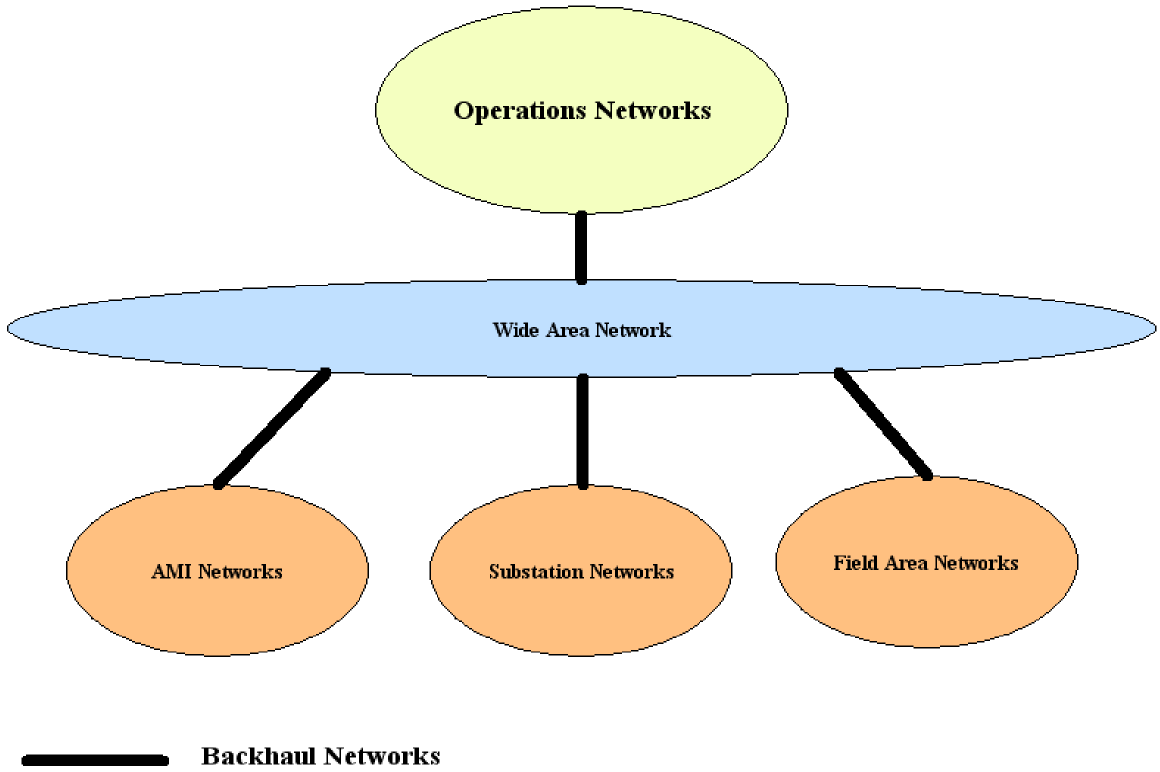
The system requirements for utilization of wireless spectrum are being developed at this time by the SG-Networks Working Group as a key element of the Open SG Users Group activity. A number of network clouds have been considered in that work, including the following to date:

- AMI Network
- Distribution Field Area Network
- Distribution SCADA Network
- Distribution Substation Network
- Internet/Extranets
- Transmission Field Area Network
- Transmission SCADA Network
- Transmission Substation Network
- Wide Area Networks

Within SG-Networks, there have also been suggestions that the Wide Area Network should perhaps be broken down into smaller elements to expose more functional subsystems, in particular the backhaul element.

This has merit considering that ultimately, the Smart Grid will consist of numerous specialized network clouds, and a series of backhaul networks to tie each cloud to an operations center function.

A simplified view of that structure is provided here.



In this view, the concept of an Operations Network is added. Backhaul is shown to and from the Automated Metering Infrastructure (AMI) network, Substation Networks, and Field Area Networks. Each of these are shown as representative clouds with backhaul requirements. All operate through a Wide Area Network (WAN).

Current Occupancy of 1800 – 1830 MHz

UTC originally recommended this band because it is used in Canada *"for the operations, maintenance and management of the electricity supply, and to update the technical requirements applicable to systems throughout these bands"*.[1]

Industry Canada indicates in the reference document that point-to-point applications will be considered in the 1800-1830 MHz band if the applicant shows a lack of alternatives in nearby bands. In addition, other rules are to be written for this band.

1 Gazette Notice SMSE-008-08, Department of Industry Radiocommunication Act Decision on Consultation SMSE-008-08 — Proposed Revisions to the Technical Requirements for Fixed Service in the Bands 1700-1710 MHz and 1780-1850 MHz, December 12, 2008

In the United States, the 1800 - 1830 MHz band is currently being utilized by the Federal Government for Point-to-Point Microwave. The details of government use are classified, but facilities are thought to exist along the Texas-Mexico border, along with unclassified facilities in nearby bands.

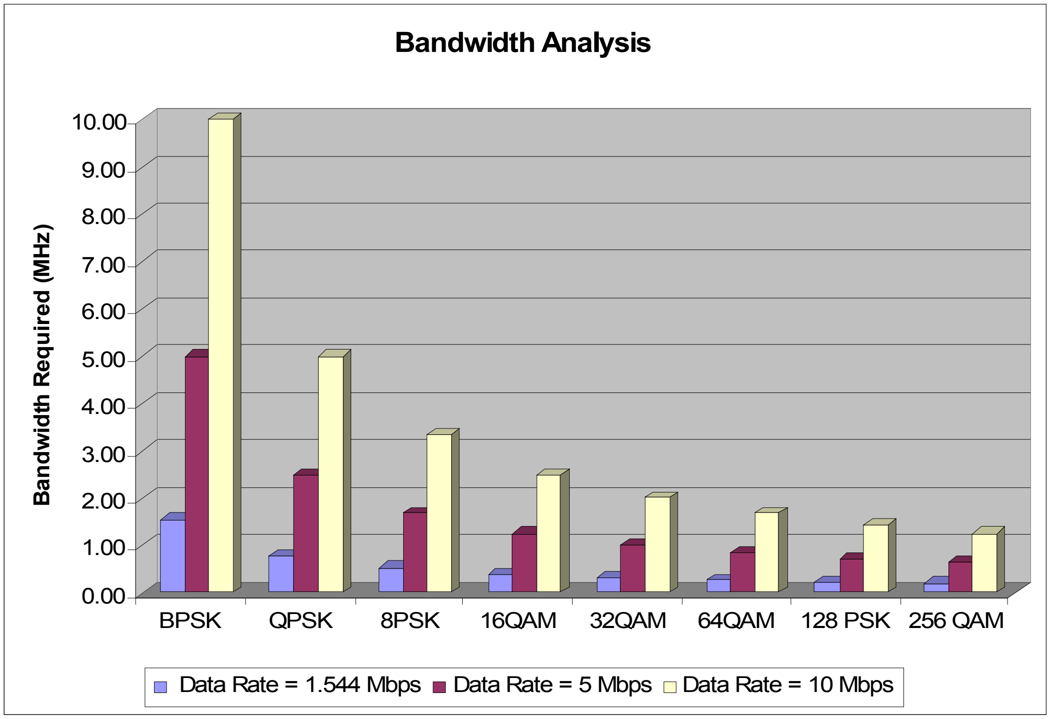
Since both Canada and the USA are using the band currently for Fixed Point to Point operations, that is the primary option considered in this analysis.

Assessment of the Band for Backhaul Operation

A total of 30 MHz can be utilized in a variety of ways. For the sake of comparison, 30 MHz defines a single channel in the 6 GHz band used for long haul point-to-point microwave applications.

The need to identify multiple channels in order to serve a variety of utilities means that for point-to-point microwave backhaul applications, each channel will necessarily be substantially smaller than 30 MHz. However, as modulation methodology is continually improving such that 256 QAM is routinely used for short microwave paths today, smaller channels have the potential to add substantially to the backhaul requirements of the Smart Grid.

For the current exploration purposes, a band plan is assumed that reserves a block of slightly less than 2 MHz in the center of the band, and minimal guard bands at the edges of the frequency allocation, making roughly 14 MHz available for transmit operation and another 14 MHz for receive operations if new point-to-point applications are considered. To gain insights into how to define channels, it helps to first examine the modulation formats available in modern microwave equipment. On a continuum from BPSK to 256 QAM, the following chart shows how much theoretical bandwidth is required, assuming no coding and no filtering for three representative bit rates.



Notice that the T1 bit rate of 1.544 Mbps can be carried in about 200 KHz using 256 QAM.

Looking at this same data in another way, one could ask "How many channels could be established in the plan as defined, if data rates were set at 1.544 Mbps, 5 Mbps, or 10 Mbps?

That graph is shown here.

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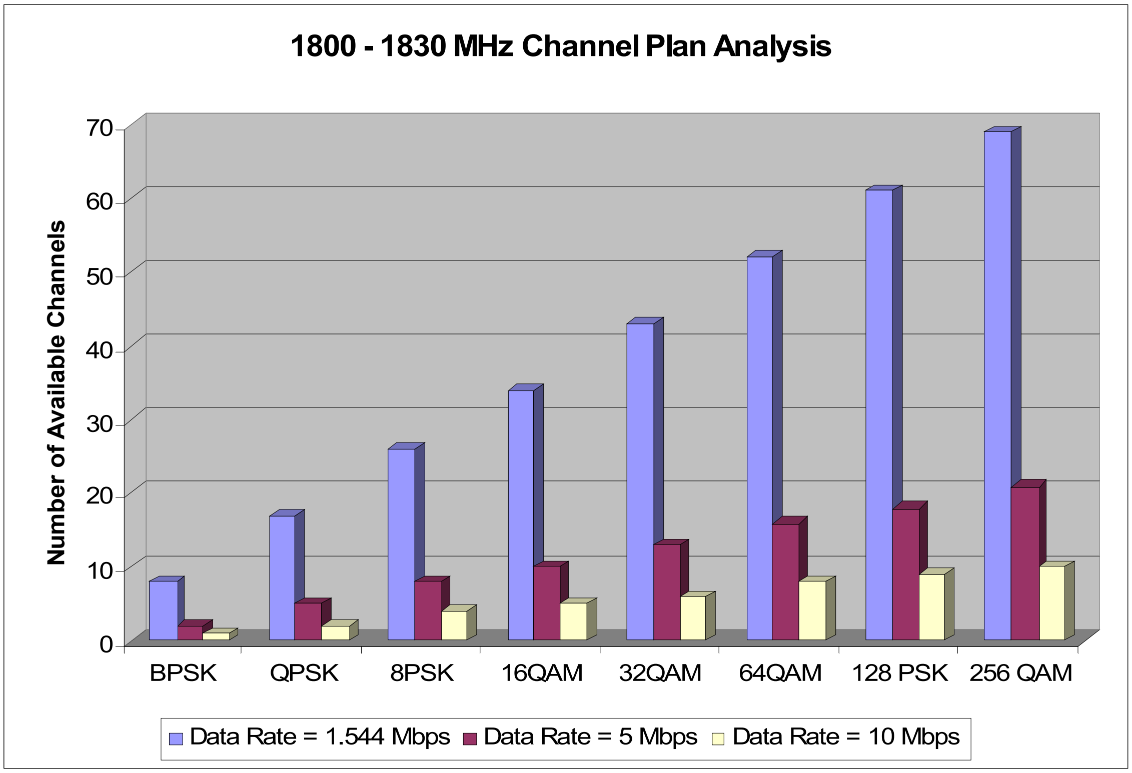

If adaptive modulation were permitted on new point-to-point microwave facilities, it would be possible to utilize the higher order modulation formats on longer paths, since they would automatically revert to lower order formats during severe fades. This is especially the case in a band where long propagation paths of 45-50 miles are routinely possible.

Note that with 256 QAM, it is possible to carry approximately 70 channels in the available 14 MHz channel space if a Data Rate of 1.544 Mbps is carried on 256 QAM. This translates to a theoretical channel bandwidth of approximately 200 KHz.

On this basis, a logical recommendation is to define the basic channel unit to be 200 KHz in 14 MHz, and allow aggregation of multiple channels for those needing higher throughput.

The use of narrow channels has another benefit. While the channel plans of the current Federal microwave systems remain classified, it is anticipated that standard frequency coordination procedures can be utilized to allow for the implementation of Smart Grid backhaul networks, while coexisting with the Federal microwave already in place. For those situations where frequency sharing simply is not possible, those narrowband channels that overlap the Federal channel in that region could be blocked off to new Smart Grid licensees.

Assessment for Area Broadband Operation

In the introduction , a number of Field Area Network and Substation Network clouds were identified. Since the electrical grid circuitry is made up of numerous components, sometimes spread over wide areas, establishing wireless communication with all of these will require a point-to-multipoint area coverage format.

In the State of Texas as an example, the total number of electrical substations has been estimated to be around 5000. A simple calculation provides potential service areas of base stations co-located with substations, if they were uniformly spread across the state.

Texas Population	20,851,820
Land Area	261,797
Average of Estimated Number Substations	5000
Average Area Coverage of Each Substation (Sq. Miles)	52
Radius in Miles of Each Substation Area	4

Essentially, this simple calculation indicates that at any point in the State of Texas, there could be an electrical substation within roughly four miles from that point. This includes the points where the Federal microwave towers are currently operational.

This matters because the implementation of wide area transmitters & receivers are routinely located on facilities owned or controlled by the utilities. Substations are ideal locations for the base stations to support substation networks, field area networks, and in many cases for AMI networks.

If a base station is constructed within four miles of a current microwave tower, the level of potential interference is shown in the calculation of the next table.

As a starting point, the EIRP density level of one watt/MHz is the same as that set for broadband operations by the FCC in the 3650-3700 MHz band.

- The calculation starts with the base station EIRP, so the transmit antenna is included.
- Free space loss yields a worst case path loss.
- A base station channel bandwidth of 5 MHz has been assumed as this would allow five separate channels with guard bands to minimize interference among base stations.
- For Smart Grid use of this band, a long term interference objective of -154 dbw/4 KHz (commercial grade operation) is assumed for point-to-point microwave receivers.

Broadband Interference Levels	
Base Station EIRP Density (watts/MHz)	1
Channel Bandwidth (MHz)	5
Effective Transmit Power in one channel (dbm)	37
Frequency (MHz)	1820
Separation Distance (miles)	4
Separation Distance (Km)	6.4
Free Space Loss	113.8
Received Interference Carrier Level (dbm/4KHz) to RX Antenna	-107.8
Objective Interference Level (dbm/4KHz)	-154.0
Margin	-46.2

The resulting 46 db negative margin cannot be resolved by any commercial microwave receive antenna, and requires substantial terrain and/or building blockage along the interference path.

As a consequence, if a broadband technology such as WIMAX or LTE were introduced into this band, the current Federal microwave systems would have to be moved into another frequency band.

Summary

The arguments of the present work summarize as follows:

- Point to Point backhaul operations can likely be implemented for Smart Grid applications on a sharing basis with existing Federal facilities
- For point to point fixed microwave operations, a minimum channel bandwidth of 200 KHz is realistic
- For broadband applications whereby LTE or WIMAX were utilized, it will not be possible for these facilities to operate co-channel with terrestrial point to point microwave facilities, and existing operations would necessarily have to be relocated to another band

Considering the classified nature of the Federal microwave facilities, some of the assumptions regarding those facilities may not be accurate, and will need revision in future work. To support that work, Micronet has established a hypothetical test network of microwave facilities along a section of the Texas-Mexico border in an adjacent band for technical evaluation of interference levels under various network implementation scenarios. As additional information on existing facilities can be made available, studies of specific interference situations created by proposed new Smart Grid facilities, can be quickly evaluated against this network.

These hypothetical sites are shown here on Google Earth.