Full | Spectrum

Private Wireless Broadband for Mission Critical Applications

Company Background

Full|Spectrum

- Company founded in 2006
- Privately held Delaware Corporation
- Headquartered in Menlo Park, California
- Privately Funded
- Strategic Partnership with Tata Elxsi
- Development teams in Sterling, Virginia; Haifa, Israel and Bangalore (28 development engineers)
- Main integration site in Sterling, Virginia

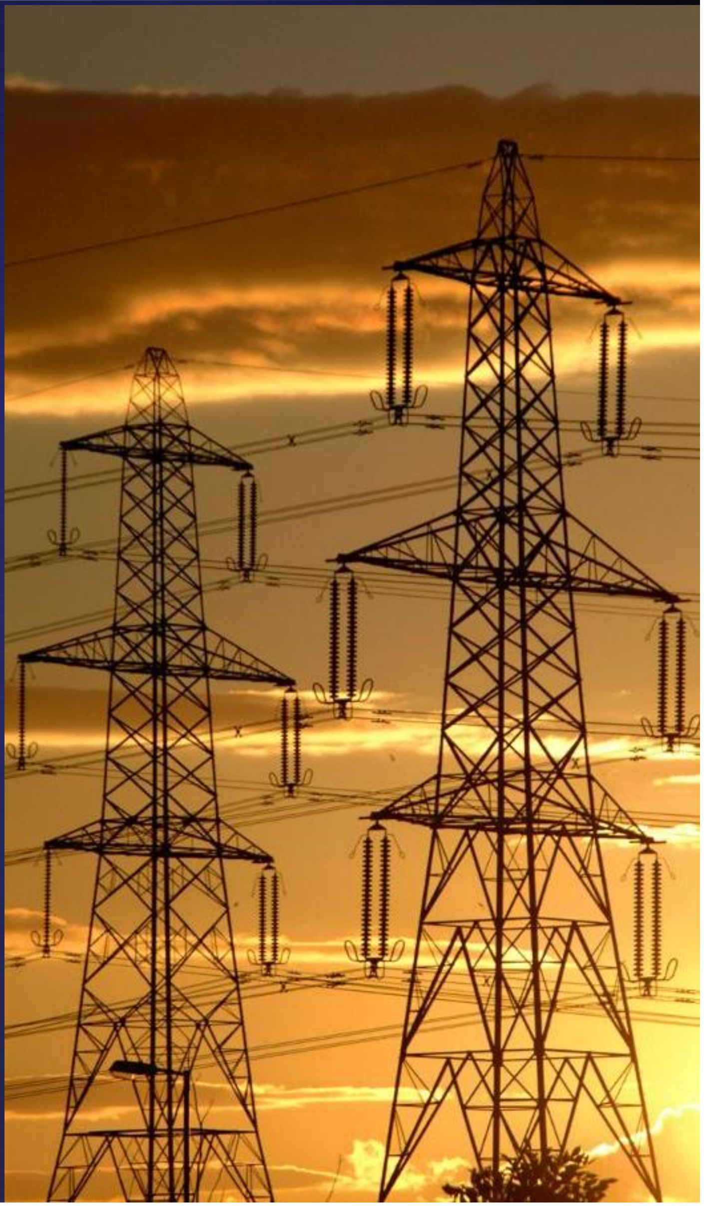
Full Spectrum Mission Statement

Full|Spectrum

Design, develop and deliver a superior range, private, mobile and fixed, broadband wireless system for mission critical customers operating over their own tower infrastructure and licensed frequencies

Mission Critical Communications Requirements

- Ubiquitous, wide-area coverage
- Broadband Fixed and Mobile Access
- Configurable QoS
- Predictable data rates and latency
- Mission critical security and availability



Existing Communications Fail to Meet their Needs

- Satellite Networks: low data rate, high latency, poor mobility

- Unlicensed Wireless: limited range, data rate degrades quickly, poor QoS, no mobility

- Public Wireless Networks: incomplete coverage, not mission critical

- Private Mobile Radio: legacy technology, low data rate

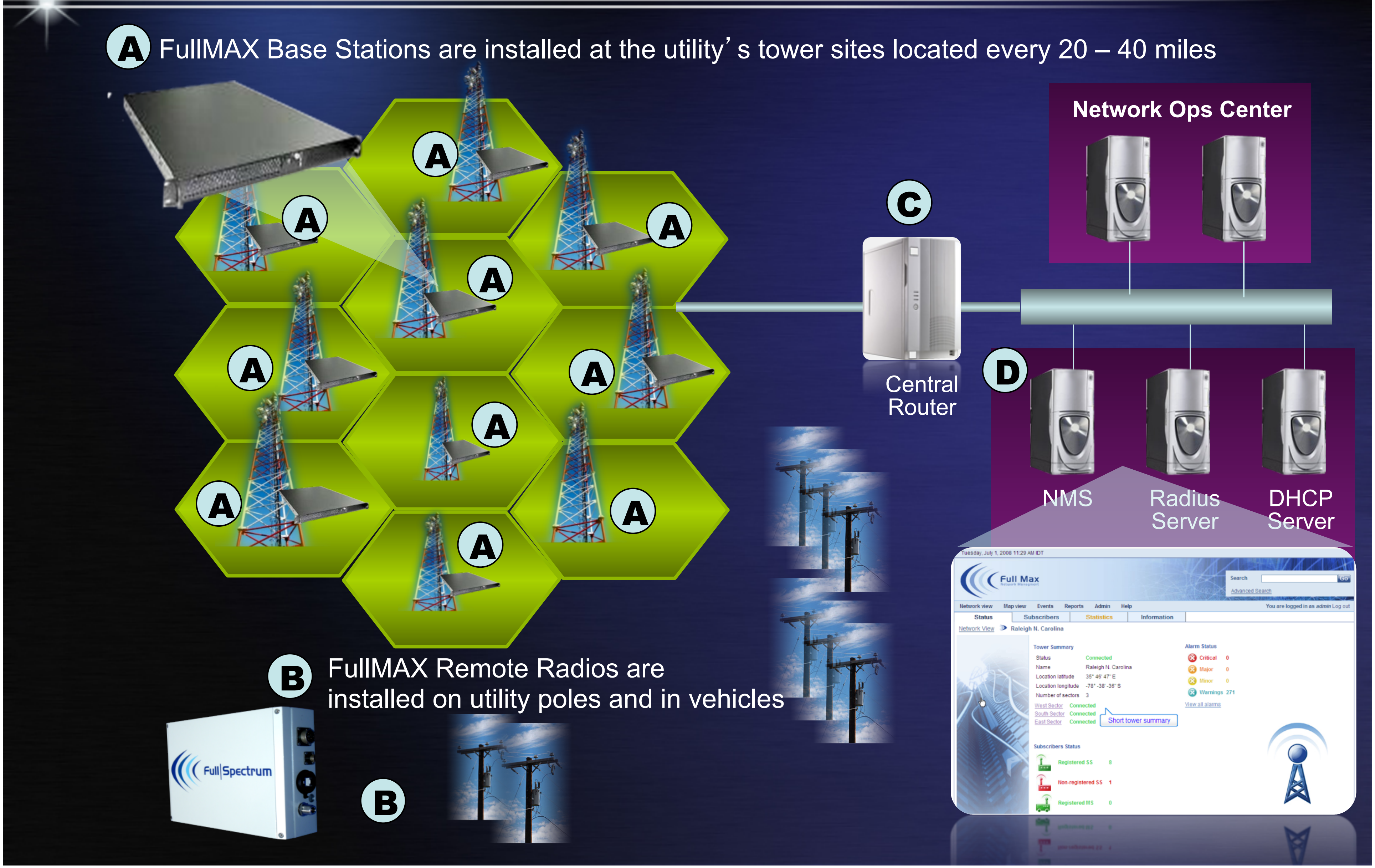
Highlights & Intellectual Property

- Extended and enhanced version of the worldwide Mobile WiMAX standard
- Uses licensed, low-band, VHF and UHF frequencies with high transmit power (up to 40 dBm) for exceptional range
- The FullMAX Software Defined Radio supports all frequencies 40 MHz to 958 MHz (tunable over the whole range)
- Supports both standard and non-standard channel sizes (200 kHz to 5 MHz)
- FullMAX leverages the utility customer's existing radio tower infrastructure and backhaul *(no new towers)*

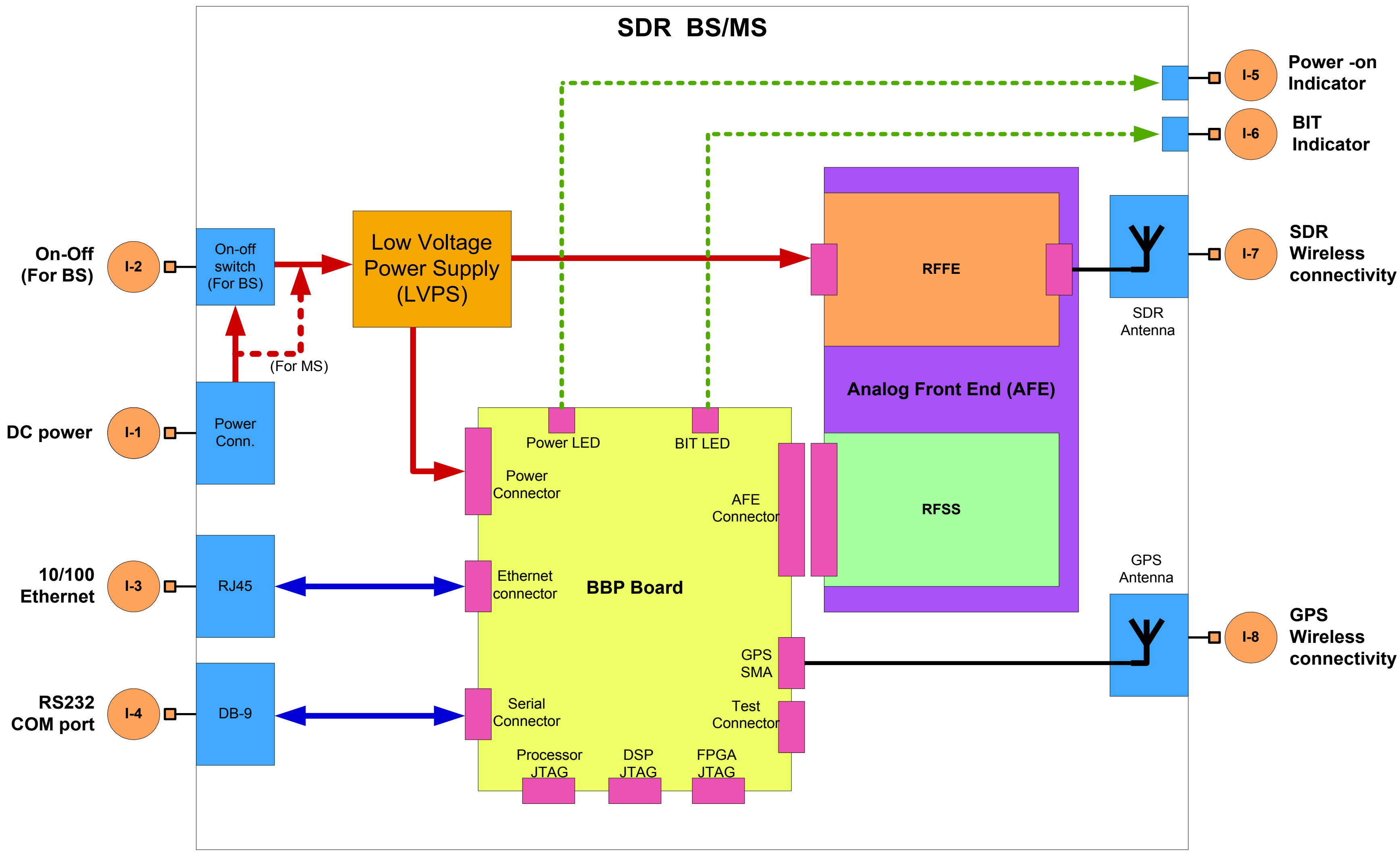
Leveraging WiMAX Features

- Scalable Orthogonal Frequency Division Multiple Access (SOFDMA)
  - High spectral efficiency
  - Efficient implementation using Fast Fourier Transform (FFT)
  - Robust against narrow-band co-channel interference.
  - Robust against intersymbol interference (ISI) and multipath fading
- Adaptive modulation and encoding schemes
  - QPSK ½ to 64 QAM ¾
- Partial Use of Sub-Channels (PUSC)
  - Allows for more efficient sectorization across narrow channels
- Quality of Service (QoS) mechanisms UGS - Unsolicited Grant Service
  - ertPS - Extended Real-time Polling Service
  - rtPS - Real-time Polling Service
  - nrtPS - Non-real-time Polling Service
  - BE - Best Effort

FullMAX System Architecture



FullMAX SDR Hardware Architecture
Base Station, Mobile and Fixed Station Radios



The FullMAX Software Defined Radio (SDR) Architecture

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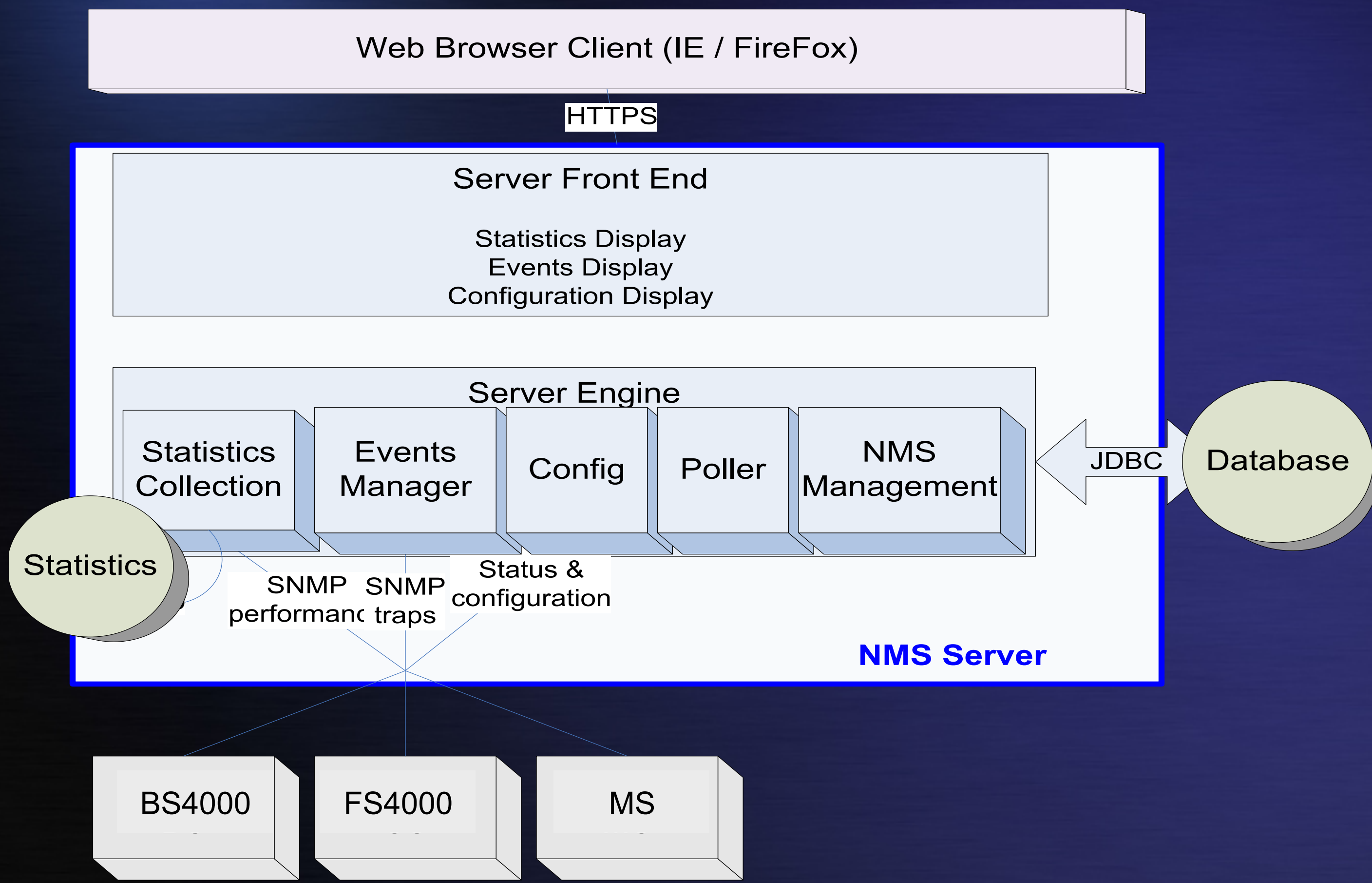
FullMax BS/MS SW Architecture

PHY Layer	MAC Layer	Complementary embedded SW
Non standard WiMAX BS/MS PHY capabilities	Non standard WiMAX BS/MS MAC capabilities	General purpose embedded software
Generic WiMAX-e BS/MS PHY layer	Generic WiMAX-e BS/MS MAC Layer	
Basic SW Tools	Monta Vista Linux OS & BSP	
TI 6482 Himalaya DSP & Xilinx Spartan 3A FPGA	PowerQuicc III 8548E processor	

FullMAX BS1000
Base Station

FullMAX FS4000 / MS4000

NMS Architecture



Why Full Spectrum?

- Superior coverage compared to any competing broadband wireless system
- Wide frequency range and channel sizes
- High throughput without losing robustness
- Highly scalable with the ability to reconfigure the channel size or adding new frequencies
- Single systems supports both fixed and mobile users
- State of the art software definable platform

FullMAX has superior range

Full|Spectrum

- Superior digital receiver sensitivity at both the BS and at the SS.
- High Power Transmission
- Operation in low frequencies

FullMAX has superior range

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- Superior digital receiver sensitivity at both the BS and at the SS.
  - The receiver sensitivity at 500 KHz wide channel is -107 dBm.
    - High performance LNA with 5 dB Noise Figure at both the BS and at the MS
    - The digital processing at the receiver meets the theoretical CINR performance with negligible implementation loss. For example, the minimum CINR for error free operation at QPSK with CC Rate ½ is 5 dB.
- High Power Transmission
  - Both the Base Station and high power subscriber station can transmit up to 40 dBm (10 watts).
- Operation in low frequencies down to 40 MHz which offers superior propagation and obstacle penetration.

FullMAX has superior range

- FullMAX coverage will be further improved using the following:
  - Power for low modulations can be increased to 43 dBm (20 watts). This can be done with minimal software changes.
  - Operating in a single subchannel provides a 4.7 dB improvement on the DL and 6 dB improvement in the UL. This is supported by the current hardware and software but has not yet been tested.
  - ARQ/HARQ provides 2 to 3 dB improvement. Both ARQ and HARQ are included in the code. ARQ was tested, HARQ has not yet been tested.
  - Utilization of GPS synchronized FS provides 2 to 3 dB gain: The GPS synchronization code needs to be ported to the FS. No hardware changes are required.
  - Utilizing CTC provides 3 dB gain. The CTC code is available but was not integrated yet in the product.

High throughput without losing robustness

- There is a trade off between robustness and throughput
- Data communication over wireless requires essential PHY and MAC Layer techniques which reduces throughput
- FullMAX adopted the WiMAX standard for robust communication over wireless and is maintaining a high throughput over narrow channels by using
  1. Programmable asymmetrical and reverse asymmetrical TDD framing
  2. Programmable TDD frame size
  3. Compression Techniques (PHS and RoHC)
- Adaptive Modulation and Coding

Superior throughput without scarifying robustness

- Configurable TDD framing
  - TDD framing offers a significant advantage for asymmetrical and reverse asymmetrical applications (e.g., SCADA). This translates into better average frequency utilization. As an example, for a SCADA application with 1/3 of the traffic in the DL and 2/3 of the traffic in the UL, an FDD based solution reduces frequency utilization by a factor of 25% relative to a TDD solution with an optimized DL:UL ratio.
- FullMax has a configurable TDD frame size. So far we tested the following three frame configurations:
  - 47 OFDMA symbols with a 32:15 ratio
  - 95 OFDMA symbols with a 65:30 ratio
  - 95 OFDMA symbols with a 29:66 ratio
- Advanced compression tools
  - FullMax employs PHS which can be optimized to compress fixed fields in the header. This is extremely effective with short packets.
  - FullMax is in the process of implementing RoHC which will further help to increase throughput.
- AMC with all modulations supported on both the DL and the UL
  - FullMax employs adaptive modulation and coding based on CINR.