FullMax BS1000/FS4000/MS4000 Radio Theory of Operation/Technical Description

Version 2.0

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1 General

a) FullMax is a WiMAX-e ((IEEE 802.16e-2005) based system. It includes BS1000 Base Stations, FS4000 remote Fixed Stations, MS4000 remote Mobile Stations standard backhaul networking equipment connecting the BS1000 Base Stations to a Router at the Network Operating Center (NOC) and a Network Management System (NMS).

b) FullMax supports the IEEE802.16e-2005 air interface protocol with modifications that are needed to enable its operation in the 700 MHz Guard band. The main modifications are:
   1) The RF front end can tune to the ,following center frequencies:
      a. 757.5 MHz
      b. 787.5 MHz

   2) The BS1000/FS4000/MS4000 operate in 700 KHz wide channels.

   3) The BS1000/FS4000/MS4000 has analog and digital filters designed to meet the FCC Part 27 spectral mask in the transmit direction and the channel selectivity in the receive direction.

c) This document describes the FullMax BS1000/FS4000/MS4000 including:
   1) BS1000/FS4000/MS4000 hardware platform description – see paragraph 2.1
   2) BS1000/FS4000/MS4000 embedded software description – see paragraph 2.2
   3) Network Management System (NMS) description – see paragraph 3.

2 FullMax BS1000/FS4000/MS4000 Radio Architecture

2.1 BS1000/FS4000/MS400 Hardware Architecture

a) The FullMax BS1000/FS4000/MS4000 radio architecture is described in figure 2-1 and 2-2 below. It consists of a Baseband Processor Board (BBP), an Analog Front End (AFE) section and a Low Voltage Power Supply (LVPS) board.

b) The BBP block diagram is described in figure 2-3. It is the heart of the FullMax radio. It is designed to perform MAC, PHY, networking, network management and other functions that are required in a broadband wireless BS and MS. The BBP has the following main characteristics:
    1) Processing resources:
        a. A TI DSP and a Xilinx Spartan 3A FPGA to execute the PHY layer
        b. A Freescale PQ3 processor to execute the MAC layer and complementary embedded software
    2) A GPS time reference module is available for synchronization[1] and for location based services.
    3) User interfaces: 100 Base T, RS232
    4) Interface to the AFE is done through a digital I/Q interface.

c) The AFE section block diagram is described in figure 2-4. It is designed for TDD operation. It has a very wide tuning range (covering frequencies between 40 MHz and 958 MHz) and it supports a wide range of channel sizes. The AFE section performs signal processing functions that are needed to deliver the signal to the antenna and to receive the signal from the antenna. The AFE consists of:
    1) A RF Small Signal (RFSS) board which contains a baseband section, an IF section and an RF section.
        a. The baseband section consists of an A/D, D/A, a programmable receive baseband filter, a programmable sampling clock synthesizer and a FPGA.
        b. The IF section consists of an IF LO, an I/Q modulator/demodulator, an IF receive channel bank and an IF transmit filter.
        c. The RF section consists of a RF LO, an RF up/down convertor, an RF receive channel bank and a RF transmit filter.
    2) A RF Front End (RFFE) board which contains a RF PA, LNA, AGC and T/R switch.
    3) The AFE employs three 8051 microcontrollers for monitoring and control of all aspects of the AFE operation. A serial interface protocol is available to support control of the master housekeeping microcontroller on the RFSS board by the main PQ3 processor on the BBP board.

[1] e.g. for TDD frame synchronization.

Note: The AFE employs a non agile external RF bandpass filter which is shown as a yellow block in the AFE block diagram in figure 4.

d) The Low Voltage Power Supply (LVPS) block diagram is described in figure 2-5. The LVPS generates all the voltages that are needed at the BBP and the AFE. It is designed for an input voltage range of 9 to 36 VDC to support power feed for a vehicle battery. An optional external power brick is available if needed to support AC or -48 VDC power feed.

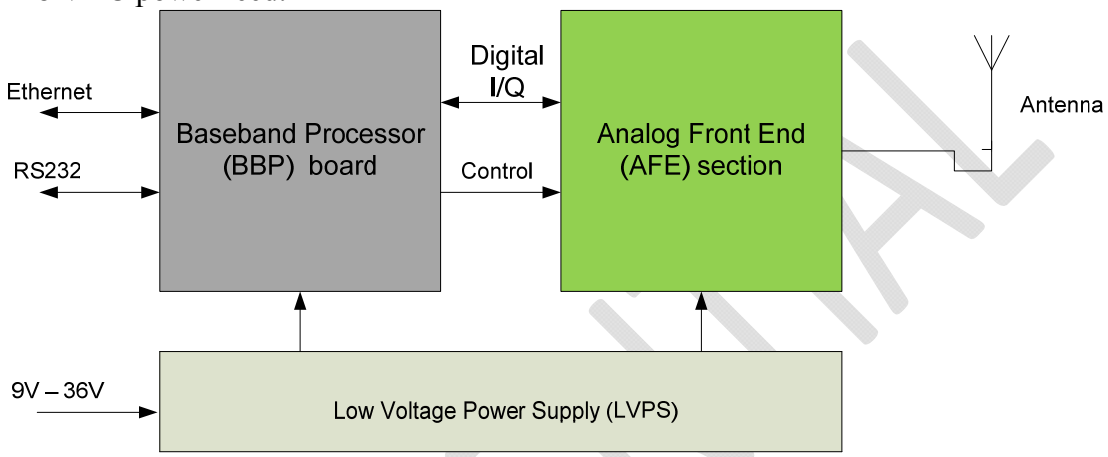

Figure 2-1: FullMax BS1000/FS4000/MS4000 High Level Architecture

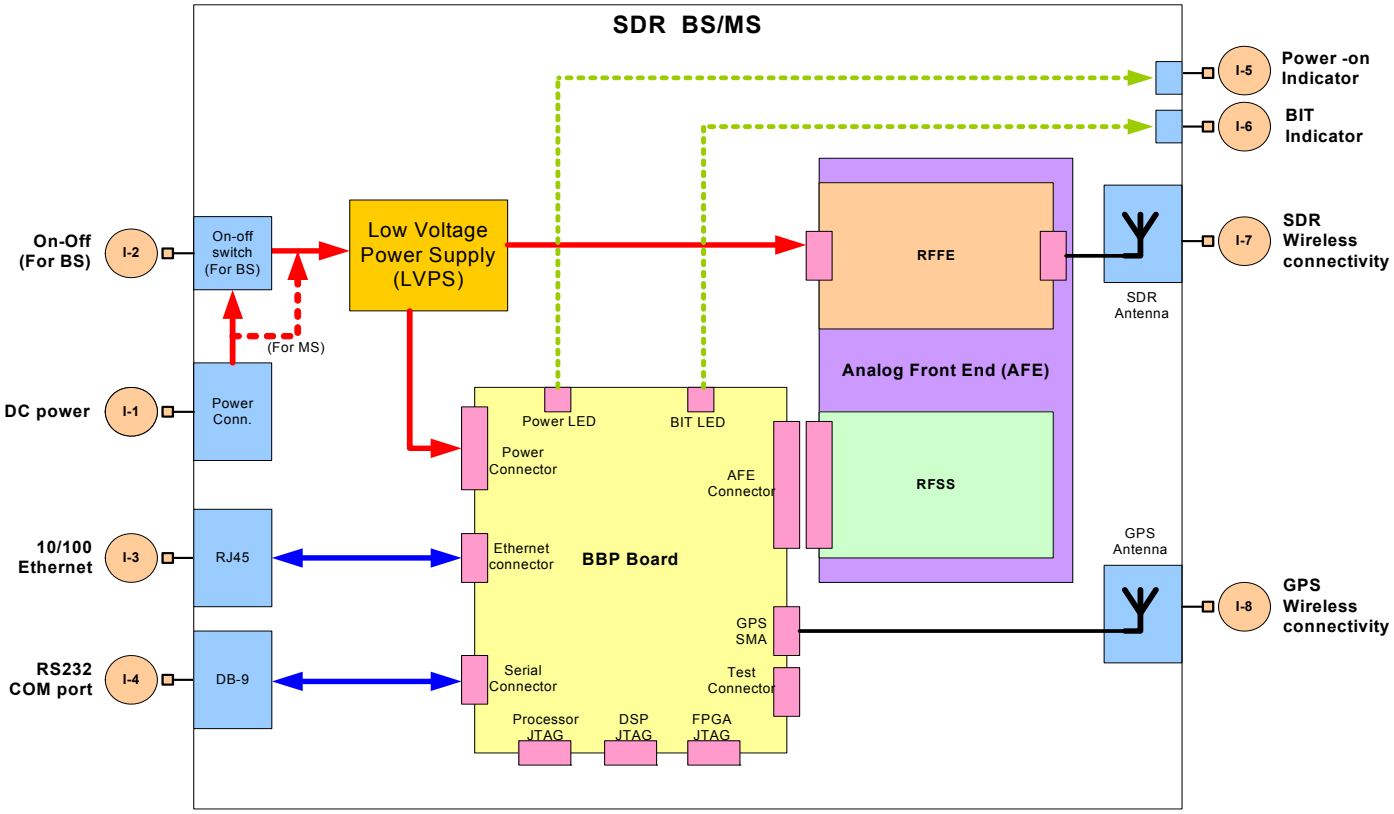

Figure 2-2: FullMax BS1000/FS4000/MS4000 Block Diagram

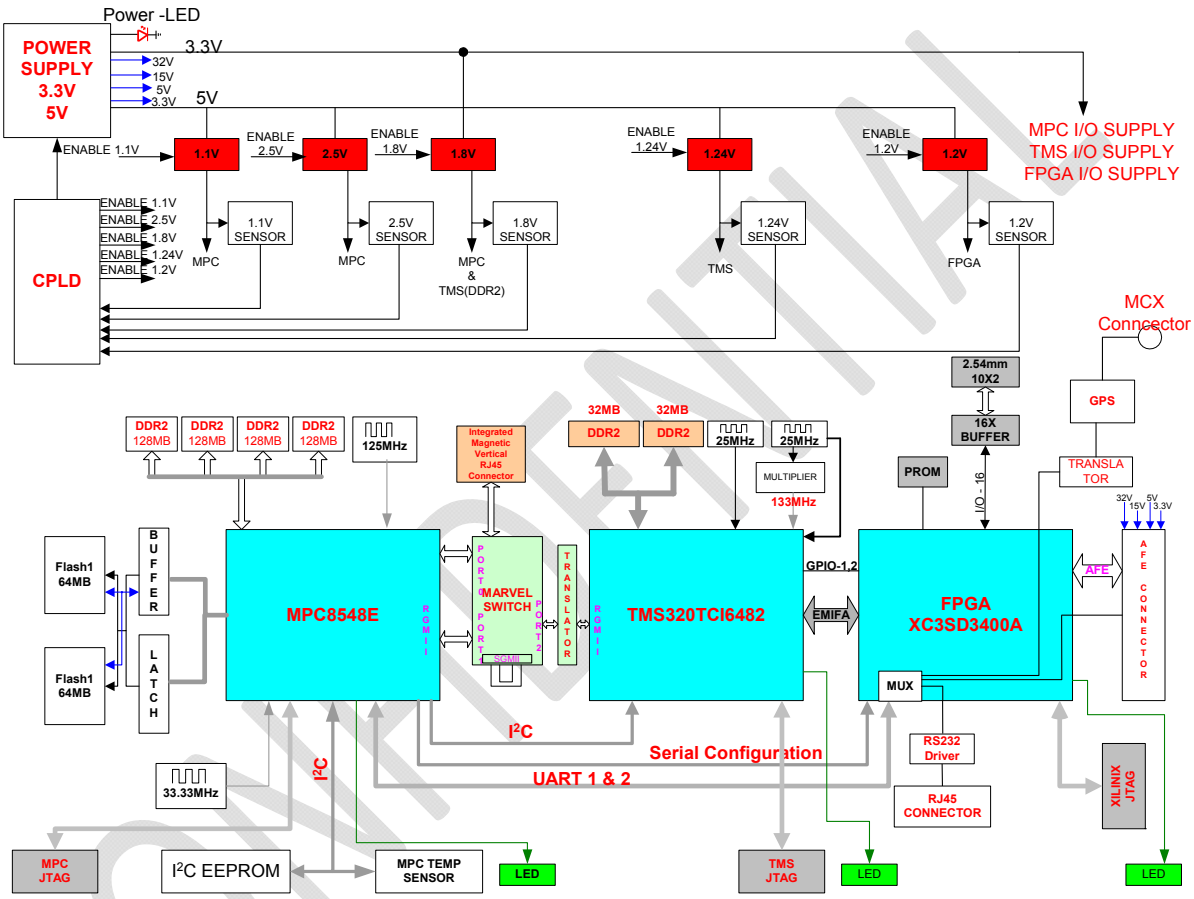

Figure 2-3: Baseband Processor (BBP) Board Block Diagram

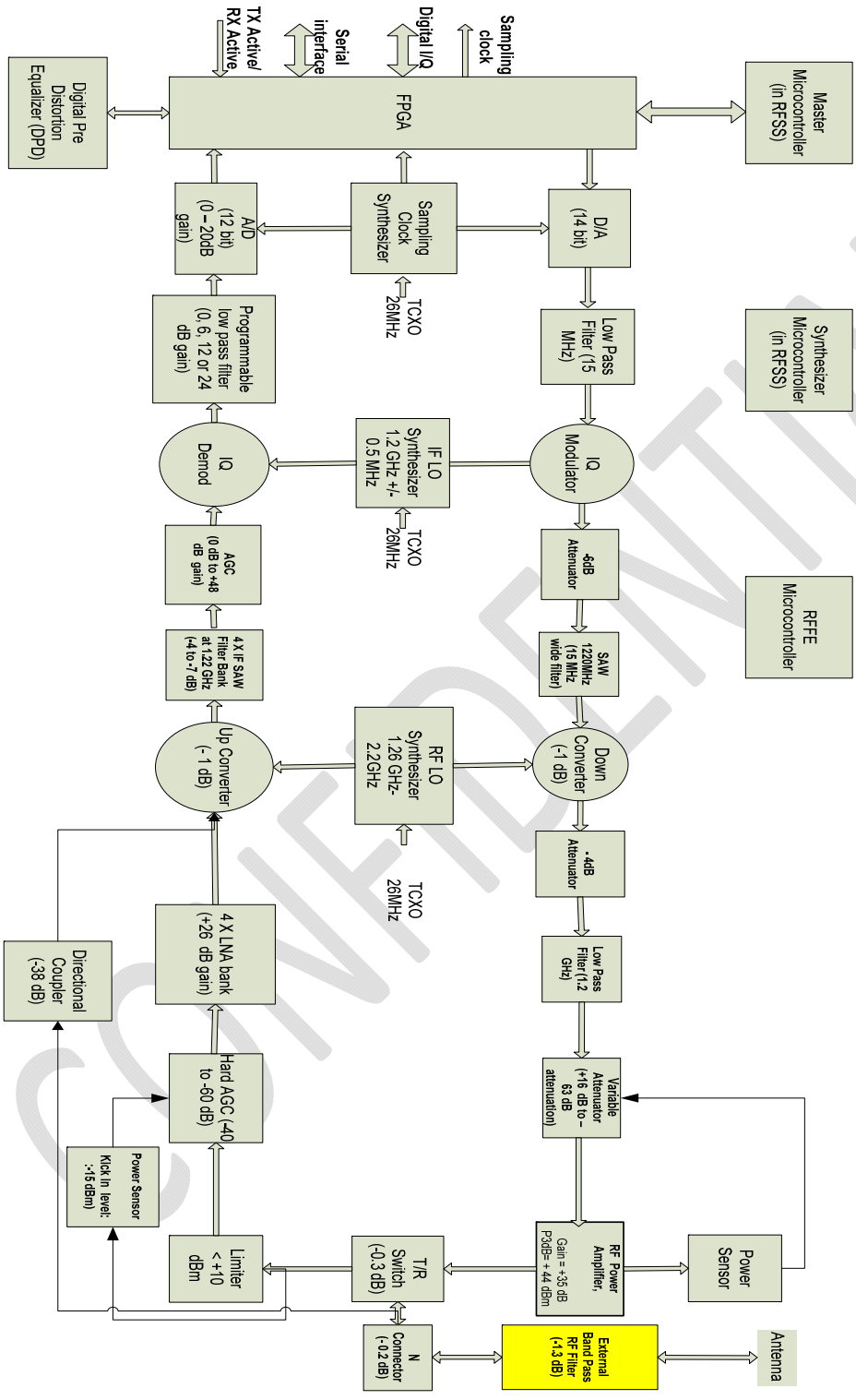

Figure 2- 4: Analog Front End (AFE) Block Diagram

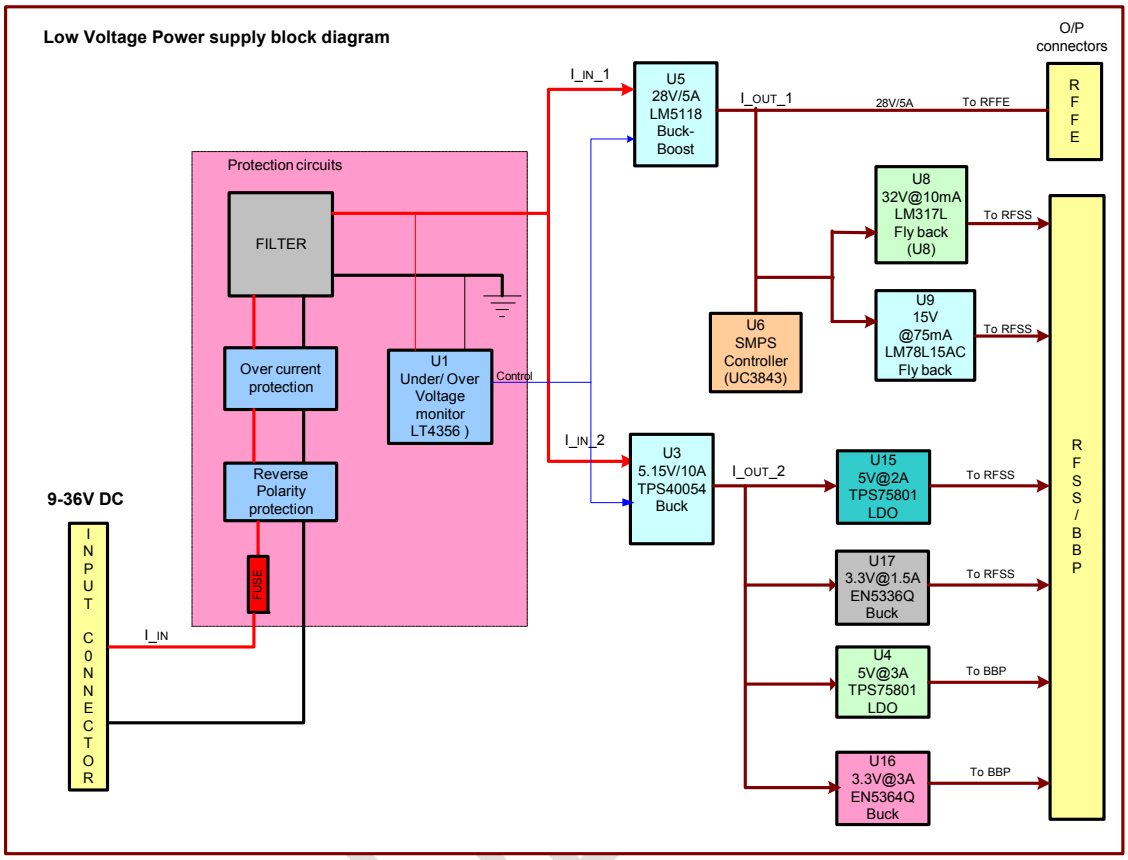

Figure 2-5: Low Voltage Power Supply (LVPS) Block Diagram

2.2 FullMax BS1000/FS4000/BS4000 Software Architecture

a) FullMax BS1000/FS4000/MS4000 software architecture is described in figure 2-6 below. It consists of PHY layer, MAC layer and general purpose embedded software components.

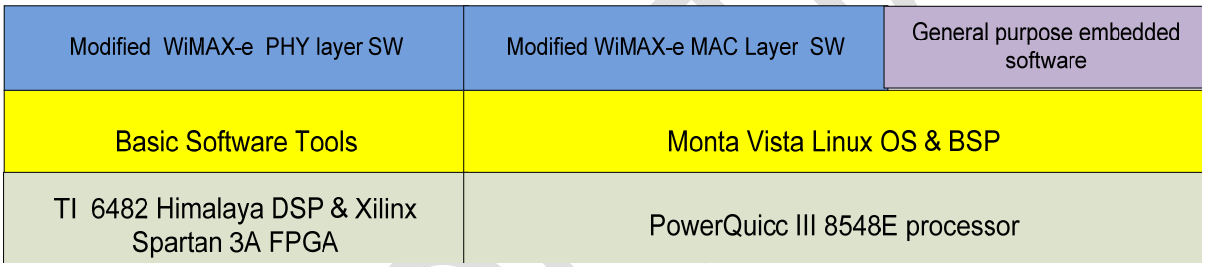

Figure 2-6: FullMax BS1000/FS4000/MS4000 software architecture

3 FullMax BS1000/FS4000/MS4000 Embedded Software Functionality

a) FullMax BS1000/FS4000/MS4000 supports the MAC and PHY layer requirements as defined in the 128 FFT variant of the "WiMAX Forum Mobile System Profile Release 1.0 Approved Specifications", subject to the following modifications:
   - Only Partial use of Subcarriers (PUSC) permutation mode is supported in both uplink and downlink
   - The TDD frame structure (including the size of the downlink sub-frame, the uplink sub-frame the Transmit to Receive Gap and the Receive to Transmit Gap) is programmable.
   - The center frequencies and the channel width is modified as needed to support the FCC Part 27 requirements.

b) This following paragraphs describe the other aspects of the FullMAX embedded software not covered by the "WiMAX Forum Mobile System Profile Release 1.0 Approved Specifications".

c) Networking:

- Supports communication over a 100 Base T Ethernet interface
- Supports IP host functionality: The BS1000/FS4000/MS4000 has an IP address and it supports the following IP protocols: DHCP, ARP, ICMP, TFTP, FTP, SNMP, ToD (RFC-868). Also, BS1000/FS4000/MS4000 has a read only MAC address which is programmable during manufacturing.
- Learning bridge and layer 2 forwarding: BS1000/FS4000/MS4000 supports learning bridge functionality, maintains a Table of Connected Entities (TCE) and uses it to forward packets to the correct destination (Ethernet interface, wireless interface or IP host)

d) QOS:

- Most of the QOS functionality is considered part of the MAC layer. The general purpose embedded software provides complimentary QOS functionality such as traffic prioritization.

e) Security:

- The embedded software supports encryption and authentication functionality and processes which are complimentary to the MAC layer security functionality.

f) Provisioning:

- IP address provisioning (the BS1000/FS4000/MS4000 can acquire an IP address from an external standard DHCP server or they can be manually configured with a fixed IP address.
- Time provisioning (the BS1000/FS4000/MS4000 acquires date and time from an RFC-868 Time server).
- EAP Provisioning (The BS1000/FS4000/MS4000 acquires the MSK Key from the AAA server).
- QoS Provisioning (The BS1000/FS4000/MS4000 QOS provisioning is done through configuration files).

g) Configuration:

- The BS1000/FS4000/MS4000 is configured through CLI and through SNMP commands).

h) Channel Acquisition

- The FS4000/MS4000 supports a pre-configured channel acquisition plan, i.e., a preconfigured list of channel alternatives, characterized by their center frequency and the bandwidth. The FS4000/MS4000 goes through the list and performs successive channel acquisition attempts until an attempt is successful.

- Criteria for channel acquisition success:
  - Successful registration if the FS4000/MS4000 was not registered prior to channel acquisition.
  - Successful ranging if the FS4000/MS4000 was registered prior to channel acquisition (i.e., in the case of moving to a new BS1000).

- Once a channel is successfully acquired, the parameters of the acquired channel are saved to the FS4000/MS4000 flash memory and are used as first acquisition option on FS4000/MS4000 power on.

i) Network Management Support

- The BS1000/FS4000/MS4000 has a SNMPv2c agent and it can be remotely managed by FullMax Network Management System outlined in Paragraph 4 below.

- The BS1000/FS4000/MS4000 also supports a Telnet based Command Line Interface (CLI) protocol which can be used to configure all BS1000/FS4000/MS4000 parameters.

j) Miscellaneous BS1000/FS4000/MS4000 hardware platform Management

- Remote and secure software download
- Initialization and configuration Persistence: The BS100/FS4000/MS4000 supports a CLI command that initiates the saving of the configuration in the flash. Saved configuration is used after power off.

4 FullMax Network Management System

a) Full Spectrum Network Management System (NMS) is a Web Application running at the Network Operating Center, and enables Network Operation Staff to monitor, configure and control the FullMax system (i.e., all BS1000, FS4000 and MS4000 units in the system) from any location at any given time. The NMS architecture is described in figure 4-1 below.

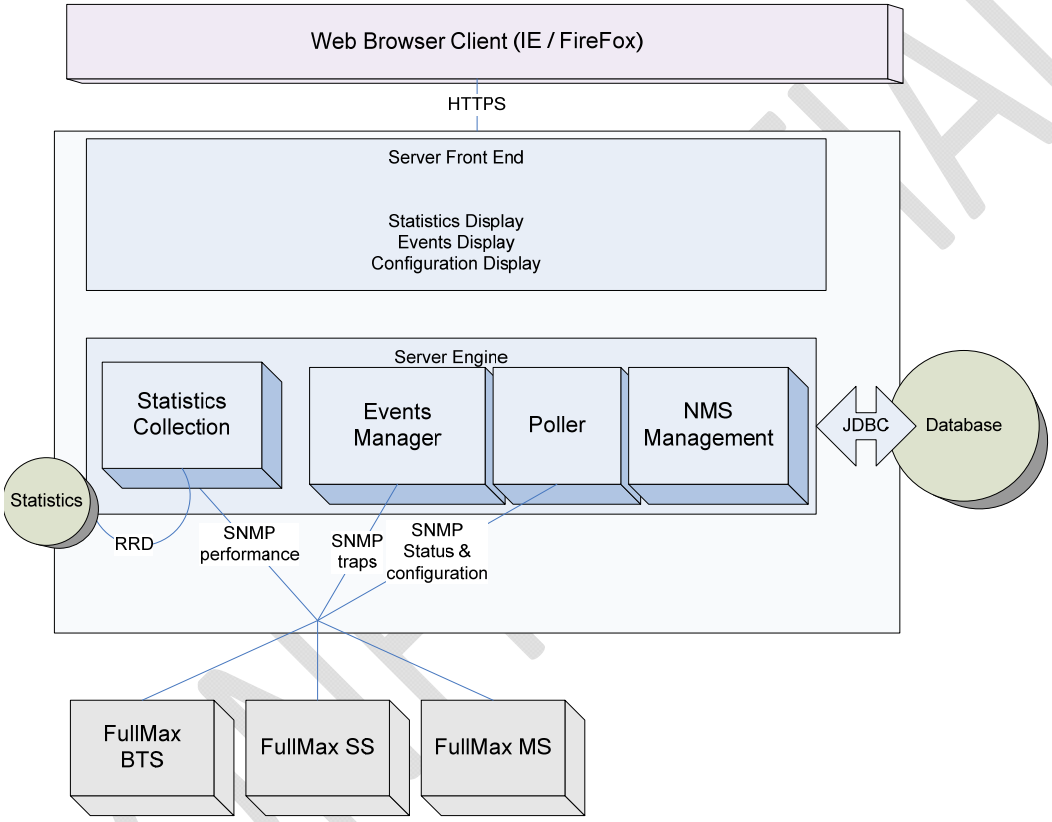

Figure 4-1 : NMS Architecture

b) The NMS user interface utilizes state of the art Web 2.0 technologies and provides a modern user experience.

c) The NMS provides a real-time map view with zooming, browsing and automatic updated of BS1000, FS4000 and MS4000 MS400 locations.

d) The NMS can be easily deployed in the customer's network, integrating with other management systems and organizational IT.

The NMS provides advanced diagnostic tools maximizing remote diagnostic efficiency. Diagnostic includes CLI access using terminal emulation embedded in the Web application, advanced real-time monitoring on any measurable parameter in the system with zooming capabilities and sending remote actions com