

Wireless Communication Network Architecture for the Smart Grid applications

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I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution.

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ABSTRACT

Smart grid is a novel initiative in the power electric distribution network that aims to provide an intelligent, self-healing and self-aware grid. The smart grid is divided into four major technological fields: telecommunications, power engineering, control and information technology. The role of communications in the smart grid is to provide adequate transmission capacity to exchange information between all the devices in the grid, supporting their operational and functional needs. Requirements of a communication network in electricity grids are not necessarily limited by the transmission capacity but also by the connectivity requirements to all the devices deployed in the network. Wireless communications, in particular the Worldwide Interoperability for Microwave Access (WiMAX), is seen as a well-recognized technology able to fulfil the requirements of smart grid's applications. The WiMAX provides wide area connectivity and the quality of service (QoS) differentiated services; the two most important issues for the communication requirements in the smart grid.

This research investigates the performance of a WiMAX-based network architecture used to support the communications needs of the smart grid applications. It proposes communications network architecture, presents the simulation model and performance results using OPNET simulation models. Simulation results are compared with analytical calculations of path loss, network capacity, and delay constraints for multiple smart grid applications, such as smart metering, consumer demand control and emergency sensor messaging.

The simulation results demonstrate that the WiMAX network could be used as an efficient and reliable communication network for the smart grid applications fulfilling the coverage needs and application QoS constraints. A communication network architecture was finally proposed by providing appropriate network configurations and inclusion of necessary algorithms in the WiMAX standard to support the different needs of the smart grid.

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LIST OF ACRONYMS

AC	Alternating current
ACK	Acknowledge
AMC	Adaptive Modulation and Coding
AMI	Automatic Metering Infrastructure
AMR	Automatic Meter Reading
API	Application Programming Interface
ARQ	Automatic Repeat Request
BAN	Business Area Network
BE	Best Effort
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
BWReq	Bandwidth request
CBS	Capacitor Bank Controller
CDMA	Code Division Multiple Access
CDRR	Customized Deficit Round Robin
CID	Connection Identifier
CINR	Carrier to Interference Noise Ratio
CIS	Customer Information System
CRC	Cyclic Redundancy Check
DA	Distributed Automation
DAC	Distributed Application Controller
DCC	Data Control Centre
DCD	Downlink Channel Descriptor
DERs	Distributed Electric Resources
DG	Distributed Generators
DHCP	Dynamic Host Configuration Protocol
DL	Down Link
DLC	Direct Load Control
DMS	Demand Management System
DRA	Dynamic Resource Allocation
DRR	Deficit Round Robin

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DRRF	Deficit Round Robin Fragmentation
DSA	Dynamic Service Addition
DSC	Dynamic Service Change
DESCADA	Distributed SCADA
DSD	Dynamic Service Deletion
DSEM	Demand Side Energy Management
DSM	Demand Side Management
EAN	Extended Area Network
EDF	Early Deadline First
EIRxP	Equivalent Isotropic Received Power
EMS	Energy Management System
EPRT	Expected Packet Rate Time
EPS	Electric Power System
ERTPS	Extended Real-Time Polling Service
ESI	Energy Services Interface
EUMD	End User Measurement Device
EVSE	Electric Vehicle Service Element
FAN	Field Area Networks
FCH	Frame Control Header
FFT	Fast Fourier Transform
FiFo	First-In First-Out
FTP	File Transfer Protocol
FUSC	Full Usage Sub-Channel
GIS	Geographic Information System
GLL	Geographic Latitude and Longitude
GMSH	Grant Manager Sub-Header
GPS	Global Position System
GSM	Global System for Mobile Communications
HAN	Home Area Network
HARQ	Hybrid Automatic Repeat Request
HCS	Header Check Sequence
HVAC	Heating, Ventilating, and Air Conditioning
HVDC	High Voltage Direct Current
IAN	Industrial Area Network
ICT	Information and Communication Technologies
IE	Information Element
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IHD	In Home Device
IP	Internet Protocol
IPT	Inter-Polling Time
ISO	Independent System Operator
ISO	International Standard Organization
IT	Information Technology

LIST OF ACRONYMS

LAN	Local Area Networks
LDC	Load Control Device
LMS	Load Management System
LoS	Line-of-Sight
LTE	Long Term Evolution
LWDF	Light Weight Deadline First
M2M	Machine to Machine
MAC	Media Access Controller
MAN	Metropolitan Area Network
MCS	Modulation and Coding Scheme
MDM	Master Data Management
MDRR	Modified Deficit Round Robin
ML	Maximum Latency
MPLS	Multiprotocol Label Switching
MRTR	Minimum Reserved Traffic Rate
MSTR	Maximum Sustainable Traffic Rate
MTU	Maximum Traffic Unit
NAN	Neighbourhood Area Network
NIST	National Institute of Standards and Technology
NLOS	Non-Line of Sight
nrtPS	Non-Real-Time Polling Service
ODW	Open Desktop Workstation
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiplexing Access
PDF	Probability Density Function
PLC	Power Line Communication
PM	Poll-Me
PMP	Point To Multipoint
PQ	Priority Queuing
PS	Polling Services
PUSC	Partial Usage Sub-Channel
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RFC	Request For Comments
RNG-Req	Ranging Request
RNG-Rsp	Ranging Response
RR	Round Robin
RSSI	Received Signal Strength Indicator
RTG	Receive-to-transmit Time Gap
RTO	Regional Transmission Operator
rtPS	Real-Time Polling Service
RTU	Remote Terminal Unit
SC	Single Carrier
SCADA	Supervisory Control And Data Acquisition

LIST OF ACRONYMS

SDU	Service Data Unit
SF	Service Flow
SFID	Service Flow Identifier
SG	Smart Grid
SINR	Signal to Interference Noise Ratio
SM	Smart Meter
SNR	Signal to Noise Ratio
SS	Subscriber Station
TCP	Transport Control Protocol
TDD	Time Division Duplexing
ToS	Type of Service
TTG	Transmit-to-receive Time Gap
UDC	Uplink Channel Descriptor
UDP	User Datagram Protocol
UF-DRR	Uniformly Fair Deficit Round Robin
UGI	Unsolicited Grant Interval
UGS	Unsolicited Grant Service
UL	Up Link
UMTS	Universal Mobile Telecommunications System
UPI	Unsolicited Polling Interval
UTC	Universal Time Coordinated
VCR	Voltage Regulator Controller
VPN	Virtual Private Networks
WAN	Wide Area Networks
WBN	Wireless Broadband Networks
WFQ	Weight Fair Queuing
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WN	Wireless Network
WRR	Weight Round Robin