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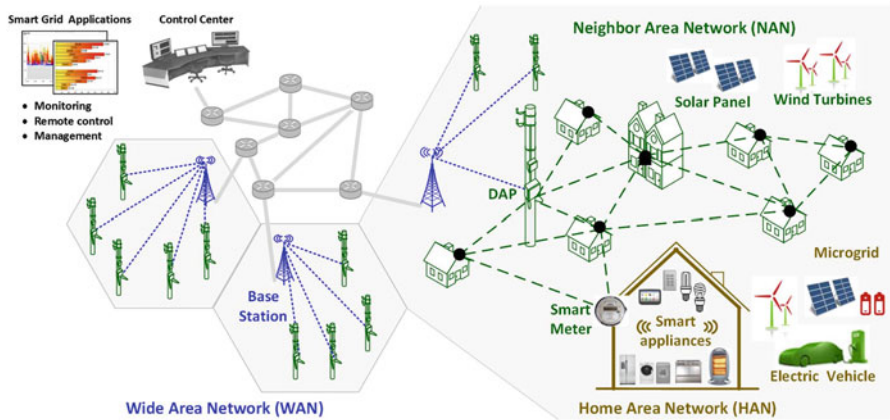
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Wireless Communications Networks for the Smart Grid



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ISSN 2191-5768

ISBN 978-3-319-10346-4

DOI 10.1007/978-3-319-10347-1

Springer Cham Heidelberg New York Dordrecht London

ISSN 2191-5776 (electronic)

ISBN 978-3-319-10347-1 (eBook)

Library of Congress Control Number: 2014948258

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Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

In order to enhance the efficiency and reliability of the power grid, diversify energy resources, improve power security, and reduce greenhouse gas emission, many countries have been putting great efforts in designing and constructing their smart grid (SG) infrastructures. Smart grid communications network (SGCN) is one of the key enabling technologies of the SG. However, a successful implementation of an efficient and cost-effective SGCN is a challenging task.

This Springer brief gives a comprehensive overview of SGCN by investigating its network architecture, communications standards, and quality-of-service (QoS) requirements. Promising wireless communications technologies that could be used for the implementation of the SGCN are also addressed. In addition, two candidate protocols for the neighbor area network (NAN) segment of the SGCN are investigated and compared in order to identify their strengths, weaknesses, and feasibilities. Especially, a proactive parent switching mechanism to improve the resilience of NANs against smart meter failures is also presented and evaluated. As an attempt to identify possible future research trends, this brief also outlines a number of technical challenges and corresponding work directions in the SGCN.

The target audience of this informative and practical brief is researchers and professionals working in the field of wireless communications and networking. The content is also valuable for advanced-level students interested in architecture design, routing protocol development, and implementation of wireless mesh networks.

We would like to acknowledge the financial supports from the Natural Sciences and Engineering Research Council of Canada (NSERC) through a NSERC discovery grant and the NSERC Smart Microgrid Network (NSMG-Net) and the

Fonds Québécois de la Recherche sur la Nature et les Technologies (FQRNT) via a scholarship.

Finally, we dedicate this work to our families.

Montreal, Canada

Quang-Dung Ho
Yue Gao
Gowdemy Rajalingham
Tho Le-Ngoc

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Acronyms

| | |
|-----------------------|--|
| 1G, 2G, 3G, 4G | First, Second, Third, Fourth Generation |
| 3GPP | 3rd Generation Partnership Project |
| 6LoWPAN | IPv6 over Low-Power Wireless Personal Area Network |
| ACK | Acknowledgment |
| ADA | Advanced Distribution Automation |
| AMC | Adaptive Modulation and Coding |
| AMI | Advanced Metering Infrastructure |
| ANSI | American National Standards Institute |
| AP | Access Point |
| API | Application Programming Interface |
| APP | Application |
| AV | Autonomous Vehicle |
| BAN | Building Area Network |
| BLE | Bluetooth Low Energy |
| BT | Bluetooth |
| CAPEX | Capital Expenditures |
| CCHP | Combined Cooling, Heat, and Power |
| CDF | Cumulative Distribution Function |
| CDMA | Code-Division Multiple Access |
| CSL | Coordinated Sampled Listening |
| CSMA-CA | Carrier Sense Multiple Access with Collision Avoidance |
| CSP | Concentrated Solar Power |
| CT-IAP | Communications Technology Interoperability Architectural Perspective |
| CTS | Clear to Send |
| DA | Distribution Automation |
| DAG | Directed Acyclic Graph |
| DAP | Data Aggregation Point |
| DDoS | Distributed Denial-of-Service |
| DER | Distributed Energy Resource |
| DG | Distributed Generation |
| DIFS | Distributed Coordination Function Interframe Spacing |

| | |
|----------------|---|
| DIO | DODAG Information Object |
| DIS | DODAG Information Solicitation |
| DODAG | Destination-Oriented Directed Acyclic Graph |
| DR | Demand Response |
| DS | Distributed Storage |
| DSL | Digital Subscriber Line |
| DSSS | Direct Sequence Spread Spectrum |
| EDR | Enhanced Data Rate |
| EIFS | Extended Interframe Spacing |
| EMI | Electromagnetic Interference |
| EPS | Electric Power System |
| ETSI | European Telecommunications Standards Institute |
| ETX | Expected Transmission Count |
| FAN | Field Area Network |
| FDMA | Frequency-Division Multiple Access |
| FHSS | Frequency Hopping Spread Spectrum |
| FLIR | Fault Location, Isolation, and Restoration |
| GEO | Geographic Routing |
| GF | Greedy Forwarding |
| GPSR | Greedy Perimeter Stateless Routing |
| HAN | Home Area Network |
| HART | Highway Addressable Remote Transducer |
| HEMS | Home Energy Management System |
| HSDPA | High-Speed Downlink Packet Access |
| IAN | Industrial Area Network |
| IAP | Interoperability Architectural Perspective |
| IC | Internal Combustion |
| ICT | Information and Communications Technology |
| IEC | International Electrotechnical Commission |
| IED | Intelligent Electronic Device |
| IEEE | Institute of Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IP | Internet Protocol |
| IPv4 | Internet Protocol version 4 |
| IPv6 | Internet Protocol version 6 |
| ISM | Industrial, Scientific, and Medical |
| ISO | International Organization for Standardization |
| IT-IAP | Information Technology Interoperability Architectural Perspective |
| ITU | International Telecommunication Union |
| IoT | Internet of Things |
| LAN | Local Area Network |
| LR-WPAN | Low-Rate Wireless Personal Area Network |
| LTE | Long-Term Evolution |
| LTE-A | LTE-Advanced |
| M2M | Machine-to-Machine |
| MAC | Medium Access Control |
| MAN | Metropolitan Area Network |

| | |
|----------------|--|
| MFR | Most Forwarding Progress within Radius |
| MIMO | Multiple-Input Multiple-Output |
| MP2P | Multi-Point-to-Point |
| MPDU | MAC Protocol Data Unit |
| MTC | Machine-Type Communications |
| MTX | Mean Transmission Time |
| NAN | Neighbor Area Network |
| NFC | Near-Field Communication |
| NFP | Nearest with Forwarding Progress |
| NIST | National Institute of Standards and Technology |
| O-QPSK | Offset Quadrature Phase-Shift Keying |
| OF | Objective Function |
| OFDM | Orthogonal Frequency-Division Multiplexing |
| OFDMA | Orthogonal Frequency-Division Multiple Access |
| OMS | Outage Management System |
| OPEX | Operational Expenditure |
| OSI | Open Systems Interconnection |
| P2MP | Point-to-Multi-Point |
| P2P | Point-to-Point |
| PAP | Priority Action Plan |
| PDR | Packet Delivery Ratio |
| PEV | Plug-in Electric Vehicle |
| PHY | Physical Layer |
| PIFS | Point Coordination Function Interframe Spacing |
| PLC | Power Line Communications |
| PMU | Phasor Measurement Unit |
| PPS | Proactive Parent Switching |
| PS-IAP | Power Systems Interoperability Architectural Perspective |
| PV | Photovoltaic |
| QoS | Quality-of-Service |
| RF | Radio Frequency |
| RFID | Radio-Frequency Identification |
| RNC | Radio Network Controller |
| ROLL | Routing over Low-Power and Lossy Networks |
| RPL | Routing Protocol for Low-Power and Lossy Networks |
| RTS | Request to Send |
| SAE | System Architecture Evolution |
| SAS | Substation Automation System |
| SC-FDMA | Single-Carrier Frequency-Division Multiple Access |
| SCADA | Supervisory Control and Data Acquisition |
| SDN | Software-Defined Networking |
| SDO | Standards Developing Organization |
| SEP | Smart Energy Profile |
| SG | Smart Grid |
| SGCN | Smart Grid Communications Network |
| SGIP | Smart Grid Interoperability Panel |
| SGIRM | Smart Grid Interoperability Reference Model |

| | |
|--------------|---|
| SIFS | Short Interframe Spacing |
| SIG | Special Interest Group |
| SM | Smart Meter |
| ST | Slot Time |
| SUN | Smart Utility Network |
| TCP | Transmission Control Protocol |
| TDMA | Time-Division Multiple Access |
| TOU | Time-of-Use |
| UDP | User Datagram Protocol |
| V2G | Vehicle-to-Grid |
| VAR | Volt-Ampere Reactive |
| VM | Virtual Machine |
| VoIP | Voice over Internet Protocol |
| WAN | Wide Area Network |
| WASA | Wide Area Situational Awareness |
| WMN | Wireless Mesh Network |
| WPAN | Wireless Personal Area Network |
| WSAN | Wireless Sensor and Actuator Network |
| WSN | Wireless Sensor Network |
| WiMAX | Worldwide Interoperability for Microwave Access |