Energy Informatics

05 Networks for Smart Grids

Christian Schindelhauer
Technical Faculty
Computer-Networks and Telematics
University of Freiburg

What is Smart Grid? RFC 6272

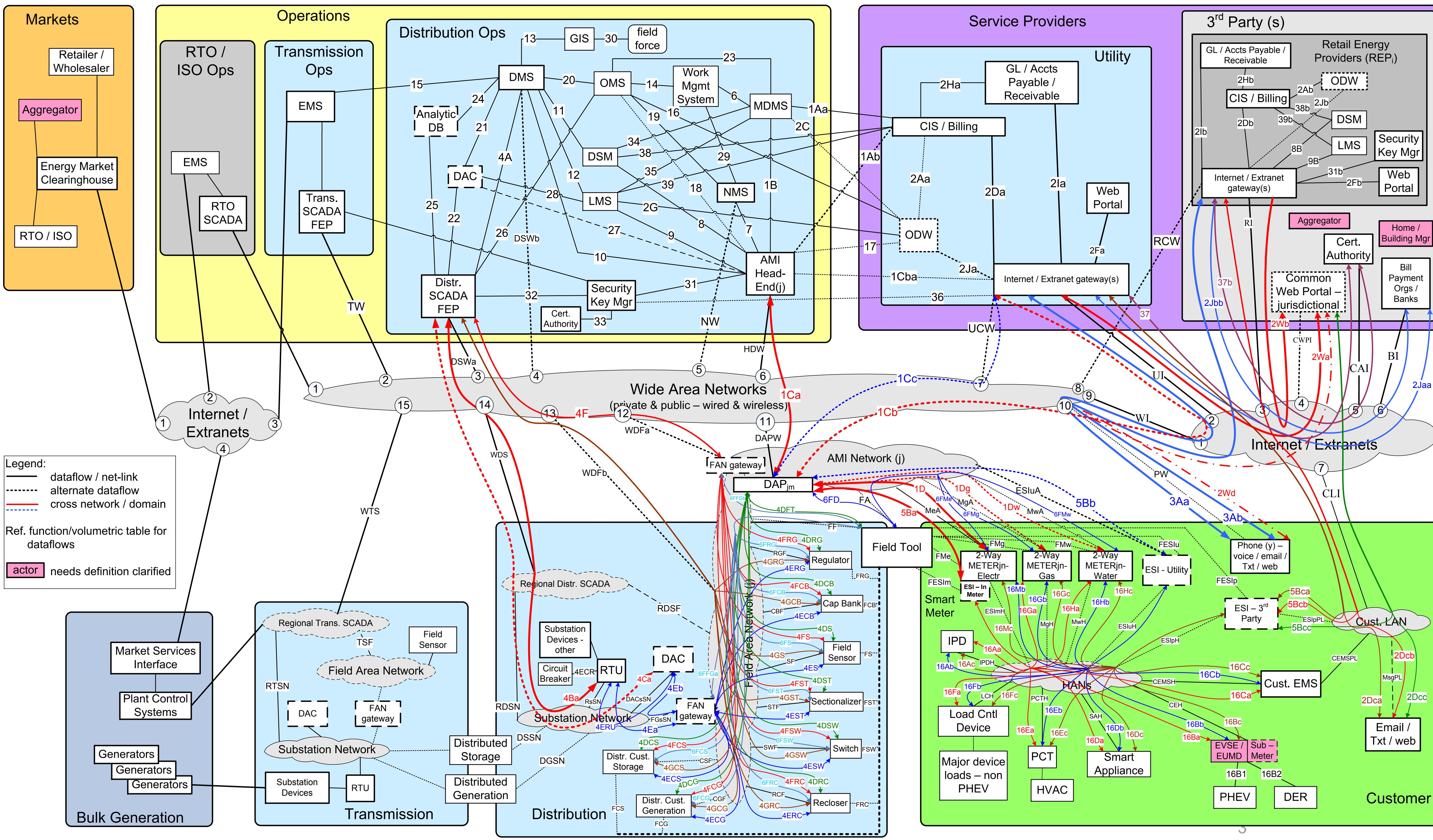
- Smart grid
  - electricity network utilizing digital technology
  - delivers electricity from suppliers to consumers
  - using two-way digital communications
  - control appliances at consumers' homes
- Features
  - saves energy, reduces costs, increases reliability, transparency.
  - net metering system
  - smart meters, integrates renewable energy
- Communication
  - between system users, operators, automatic devices
  - monitoring, tracks electricity flows

CoNe
Freiburg

Smart Grid Conceptual Actors

Smart Grid Conceptual Actors / Data Flow Diagram – Cross Domain Network Focused – OpenSG / SG-Network TF

DRAFT 14Feb2012
Base – file SG-NET-diagram-r5.1.vsd
page size: ANSI-D



European Smart Grid Programs

- CEN/CENELEC/ETSI Smart Grids Joint WG
  - A common initiative http://www.smartgrids.eu
  - European technology platform for the electricity networks of the future

- IEC Global Standards for the Smart Grid
  - Strategic Group 3 – working on Smart Grid since April ’09
  - Cooperation with NIST
  - Identified relevant IEC standards for Smart Grid
  - http://smartgridstandardsmap.com

OSGP: supported by :

OSGP ALLIANCE

CoNe Freiburg

alliander

VATTENFALL

Fortum

seas nve

LINZ AG STROM

netbeheer nederland
energie in beweging

ENERGIMIDT
nye strømninger

NRGi
Altid til stede

CIAC

MITSUBISHI ELECTRIC

ELO

aSAY Energy

V:KO

GÖRLITZ

ZIRODE
MANAGEMENT SERVICES

SECURE
SECURE METERS LIMITED
The Power of Innovation

EDMI

IBM

CONLOG
Solutions for utilities

PMT

FERRANTI
computer systems

GIZA SYSTEMS

rms
remote metering solutions

TELVENT

ubitronix
system solutions gmbh

thüga
DIE ENERGIEGRUPPE

ModemTec

ORACLE

ELTEL networks

DIEHL

EVB ENERGIE

PRI
measure ▸ inform ▸ empower

OSGP

- Goal
  - Globally-applicable standards for Information and Communications Technologies
  - Based on Echelon specifications for Data Concentrator – Smart meter communications
  - Layered protocol stack
  - common data model for utilities
  - high-performance and reliability
  - mandatory security and privacy
- Standardized by ETSI
  - European Telecoms Standards Institute (ETSI)
  - EU-recognized standards with CEN, ETCSI, CENELEC

OSGP Powerline communication

- Lower cost investment
- Lower operating cost
  - Communication cost (daily on-going communication)
- Reliability, performance
  - Proven, up to 99.8% ->99.94%-100%
  - Daily, including Load profiles
- Technical information
  - Phase, Grid
  - Outage detection
  - Grid Topology
- LV Transformer centric approach
  - Be able to run applications within a LV area (the next generation DC: Edge Control Node)

Smart Metering Standards Activities

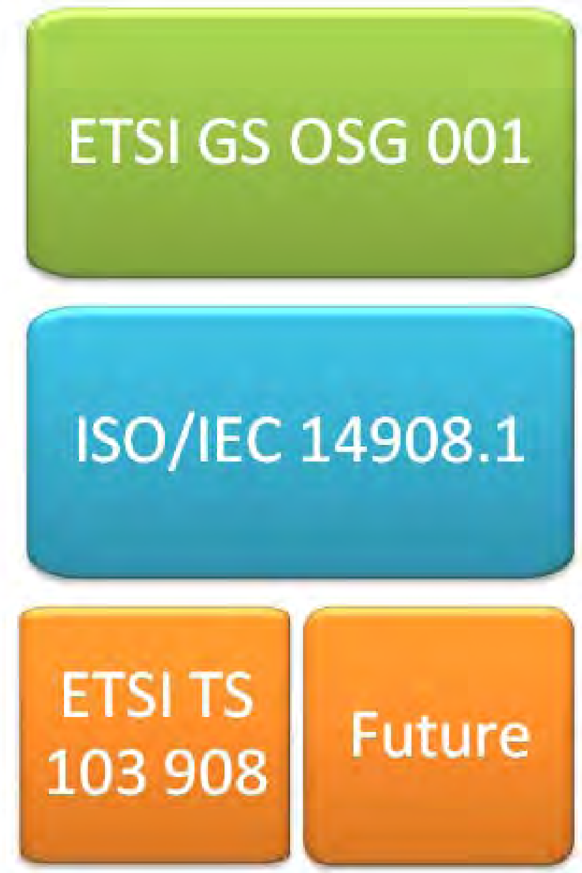
- EU: many standards
- M/441 standardization mandate
  - CEN, CENELEC and ETSI
- European OPEN meter project
  - 7th Framework Programme, finished 2012
  - http://openmeter.com/
- DLMS/COSEM: IEC 62056 / EN 13757
  - projects in Netherlands, France,

OSGP

- Layered OSI protocol stack
- ETSI Group spec GS OSG 001
  - Application layer Protocol
  - Media independent
- ISO/EN14908.1 Control Networking
  - Layers 2 to 6
- ETSI Technical spec TS 103 908
  - High performance power line communication media
  - Support many smart grid device types
- Designed for additional media
- Supported and maintained by ESNA

ETSI OSG 001

- Events allow devices to report information asynchronously
  - Alerts/alarms (e.g., tamper)
  - Conditions/thresholds being met (e.g., under voltage)
  - Exceptions detected (e.g., phase loss)
  - Self-check errors (e.g., low battery detected)
  - State or status change (e.g., season change)
- 96 events (50 basic, 46 extended)
- OSGP provides a standard way for devices to send extended events

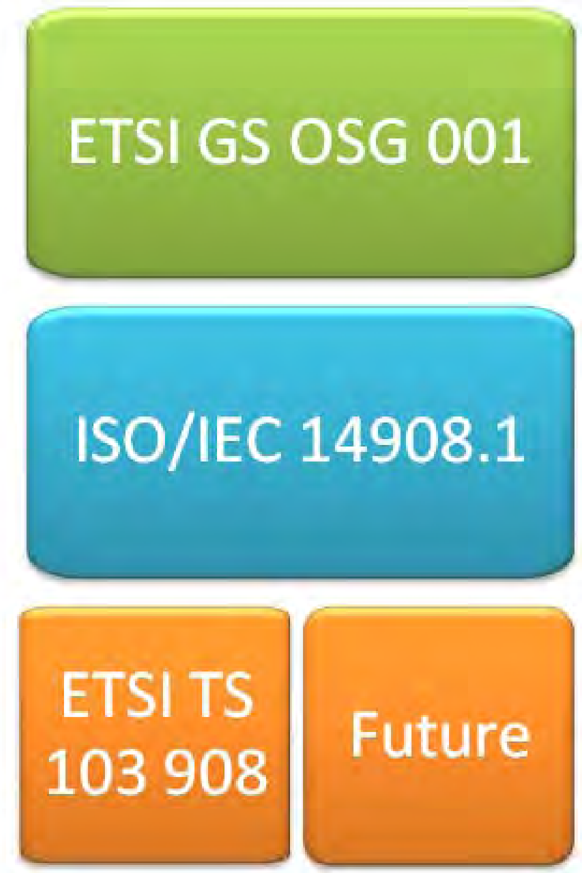


ETSI OSG 001

- Models devices as a collection of data, methods and events
  - bandwidth efficient, enabling high performance on bandwidth constrained media
  - Includes core meshing services for reliable, scalable operation
  - Built-in, mandatory security and privacy for every data exchange
  - allows commissioning, automated device discovery, automatic topology management
- Deployed in over 3.5 million smart grid devices

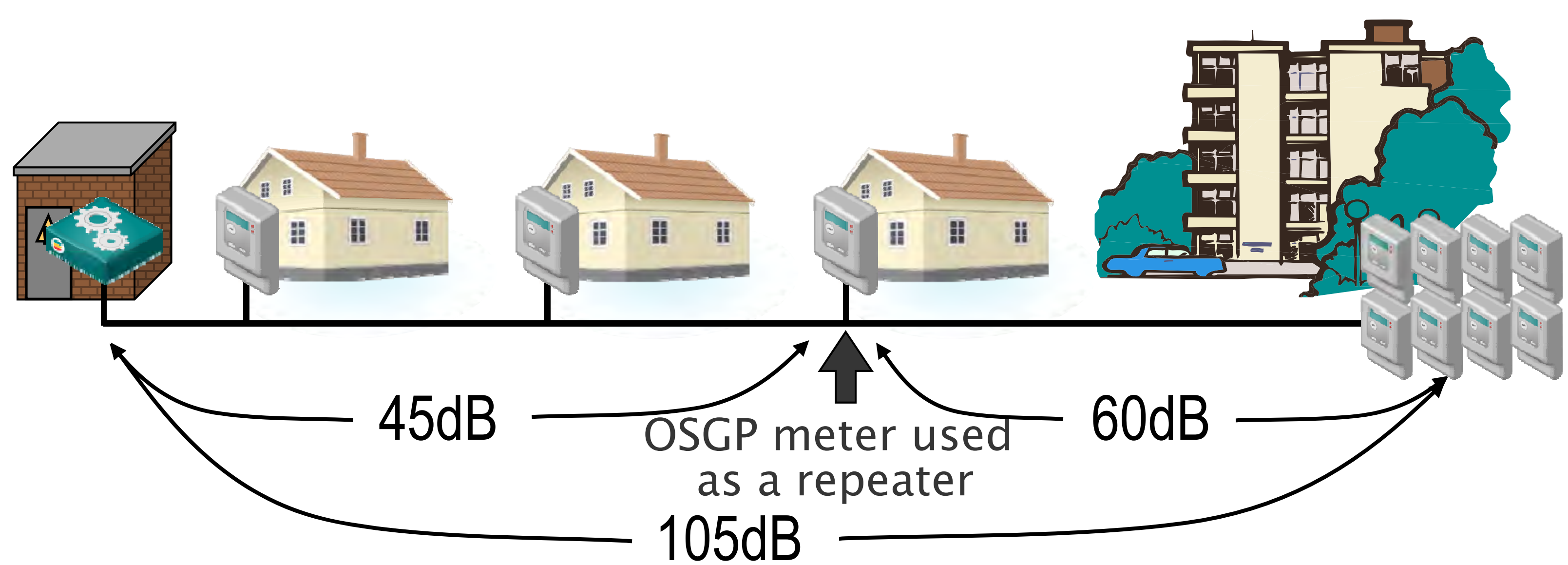
ISO/IEC 14908.1 (LonTalk)

- Optimized, multi-application control network protocol stack
  - reliable delivery, multi-cast messaging
  - Low overhead, low bandwidth
- Probably insecure:
  - Philipp Jovanovic and Samuel Neves. Dumb Crypto in Smart Grids: Practical Cryptanalysis of the Open Smart Grid Protocol 2015 https://eprint.iacr.org/2015/428 - The Cryptology ePrint Archive



OSCP Meshing

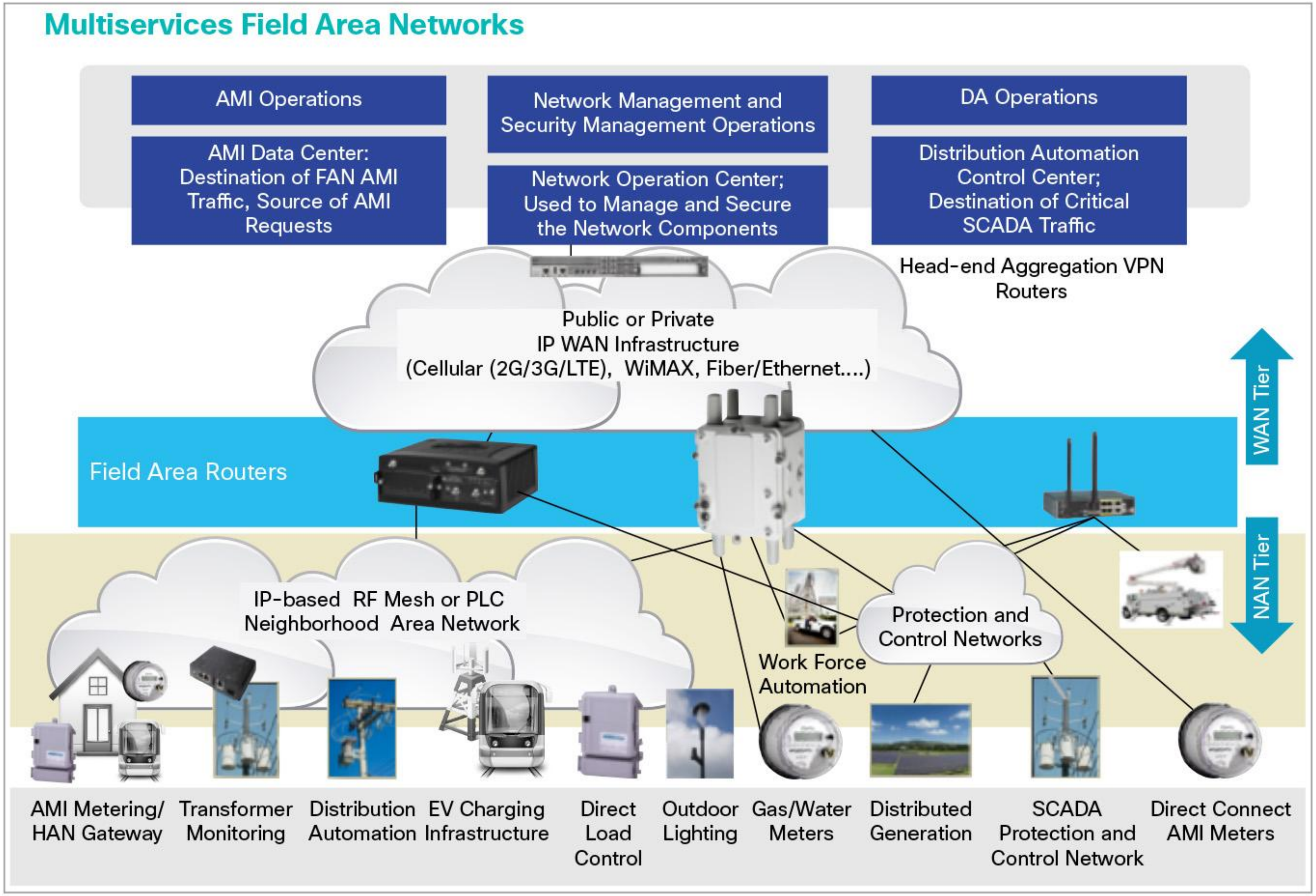
- Any OSGB device can be a repeater
- Repeating up to 16 hops
- Automatic repeater selection



ETSI TS 103 908

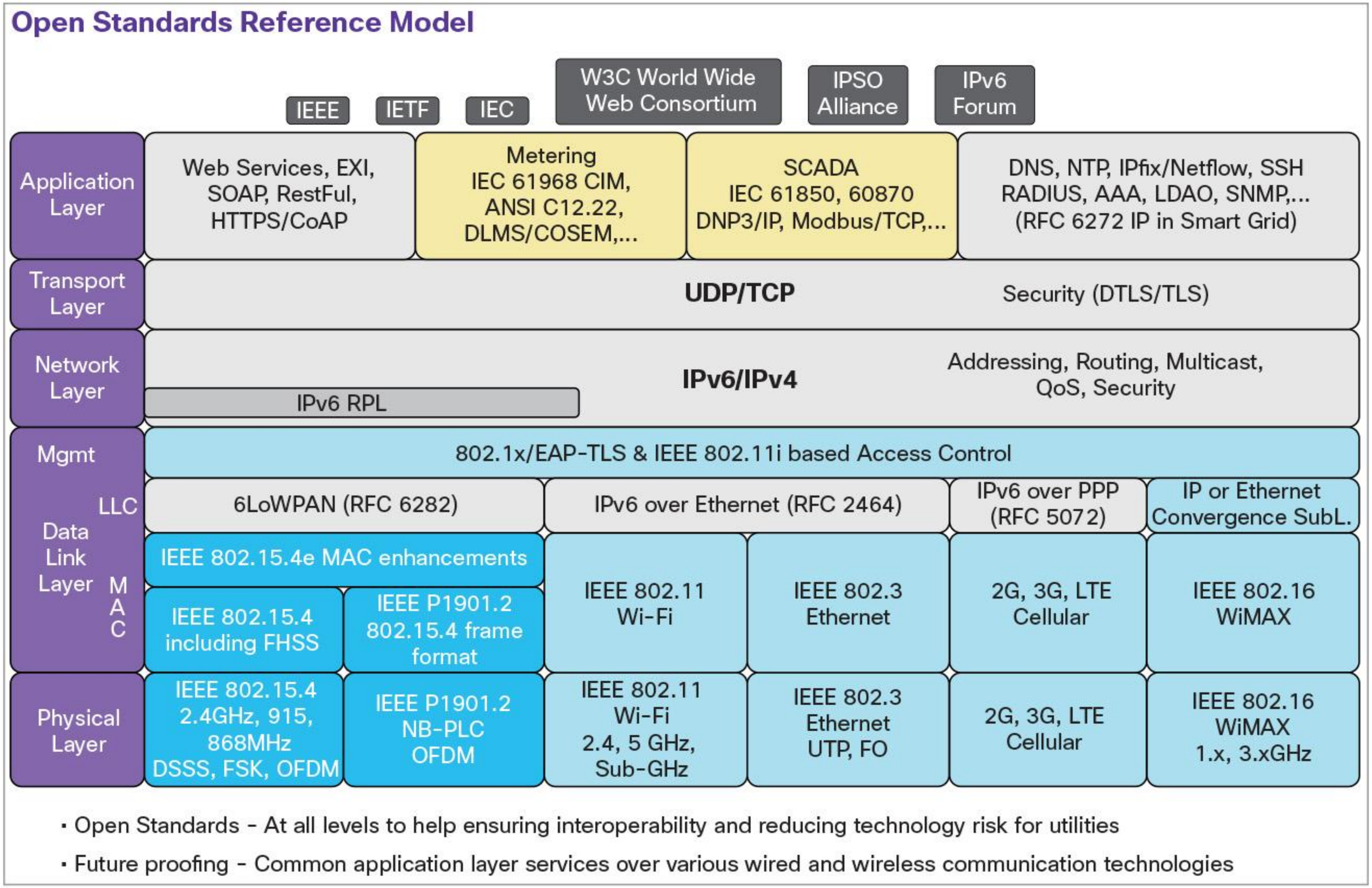
- Based on ISO/IEC 14908.3 2006 with adaptations for A-band operation, per EN 50065-1
- High-performance narrow band power line channel for control networking in the smart grid
  - Binary Phase Shift Keyed (BPSK) modulated carrier
  - 3.24 kbps raw channel data rate
  - Deployed in over 35 million smart meters and grid devices

IPv6 for Field Area Networks



http://www.cisco.com/c/dam/en_us/solutions/industries/docs/energy/ip_arch_sg_wp.pdf

IPv6 for Field Area Networks



http://www.cisco.com/c/dam/en_us/solutions/industries/docs/energy/ip_arch_sg_wp.pdf

IEEE PHY and MAC standards

- IEEE 802.15.4
  - low-power wireless PHY and MAC layers
  - for smart object networks
  - low power consumption
  - link speeds up to 250 kbps in 2.4GHz ISM frequency band
- IEEE 802.15.4g Task Group, aka Smart Utility Networks (SUN) Task Group
  - OFDM, multiple data rates, Multirate and multiregional offset quadrature phase-shift keying
- IEEE 1901.2 Power Line Communication
  - „no new-wire technology“ reuses electrical wire
  - Data rate up to 500 kbps
  - low-frequency (<500 kHz) PLC spectrum

6LoWPAN

- main focus of the 6LoWPAN WG
  - optimize the transmission of IPv6 packets over low-power and lossy networks such as IEEE 802.15.4 (WPAN)
  - Header compression
  - Fragmentation of IPv6 packets (max 127 bytes)
  - Duplicate address detection

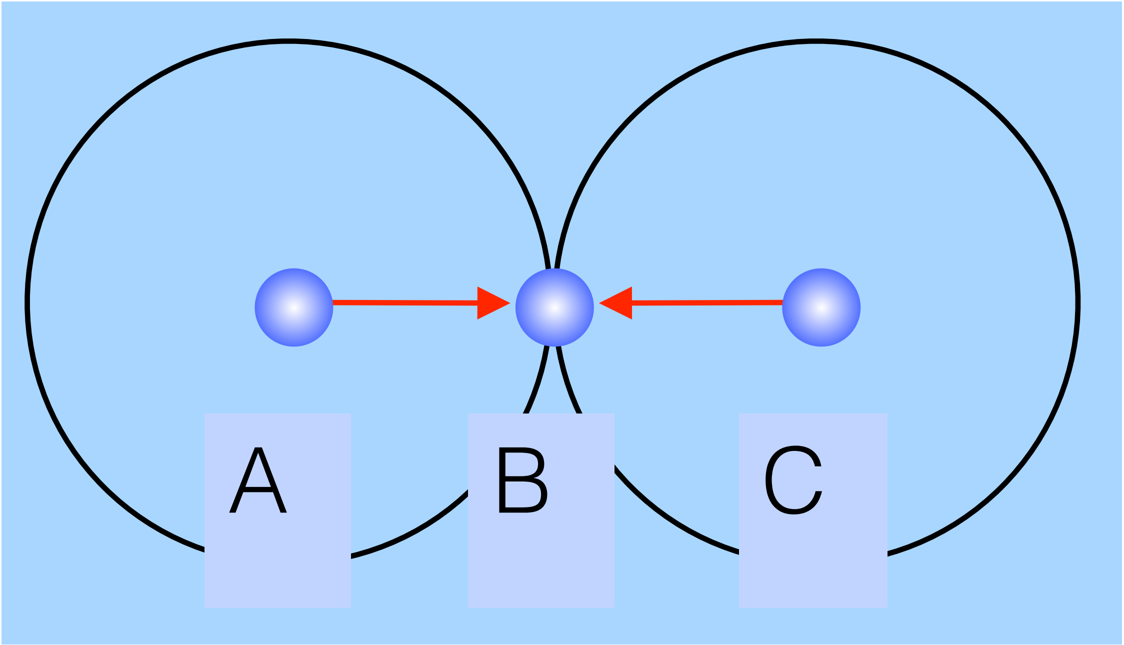
IEEE 802.15.4

- Fundamental lower network layer for wireless personal area network
- Features
  - Realtime by guaranteed time slots
  - beacon messages
  - Collision avoidance
    - CSMA/CA, random exponential back off
  - Frequency bands (868/915/2450 MHz)
    - 20-250 kbit/s
- Topologies
  - Star, Peer-to-Peer (point-to-point)

Problem of Wireless Media Access (MAC)

- Unknown number of participants
  - broadcast
  - many nodes simultaneously
  - only one channel available
  - asymmetric situations
- Collisions produce interference
- Media Access
  - Rules to participate in a network

Hidden Terminal Problem

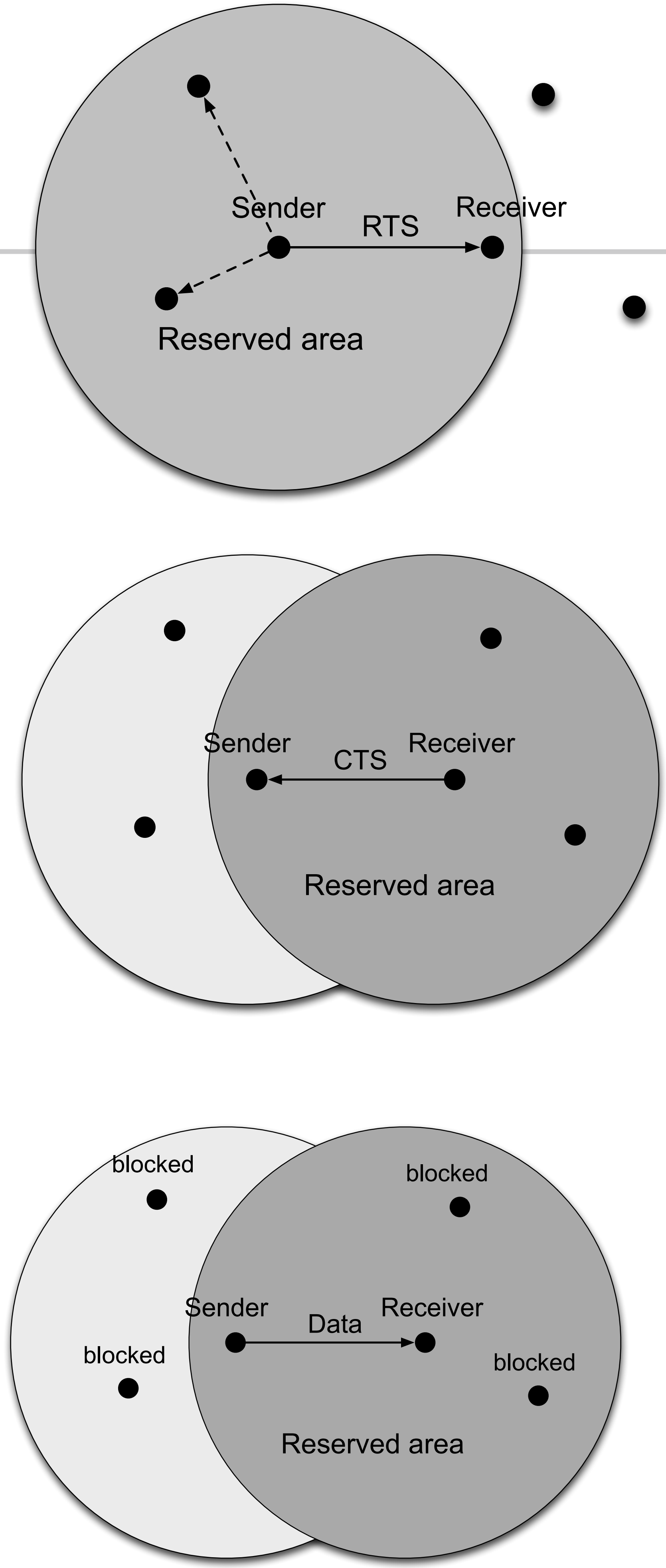


MACA

- Phil Karn
  - MACA: A New Channel Access Method for Packet Radio 1990
- Alternative names:
  - Carrier Sensing Multiple Access / Collision Avoidance (CSMA/CA)
  - Medium Access with Collision Avoidance (MACA)
- Aim
  - Solution of the Hidden and Exposed Terminal Problem
- Idea
  - Channel reservation before the communication
  - Minimization of collision cost

RTS/CTS

- Sender sends Request to Send (RTS) to B.
- Receivers answers with Clear to Send (CTS) to A
- Sender sends Data



Details for Sender

- A sends RTS
  - waits certain time for CTS
- If A receives CTS in time
  - A sends packet
  - otherwise A assumes a collision at B
    - doubles *Backoff*-counter
    - and chooses a random waiting time from {1,...,*Backoff* }
  - After the waiting time A repeats from the beginning

Details for Receiver

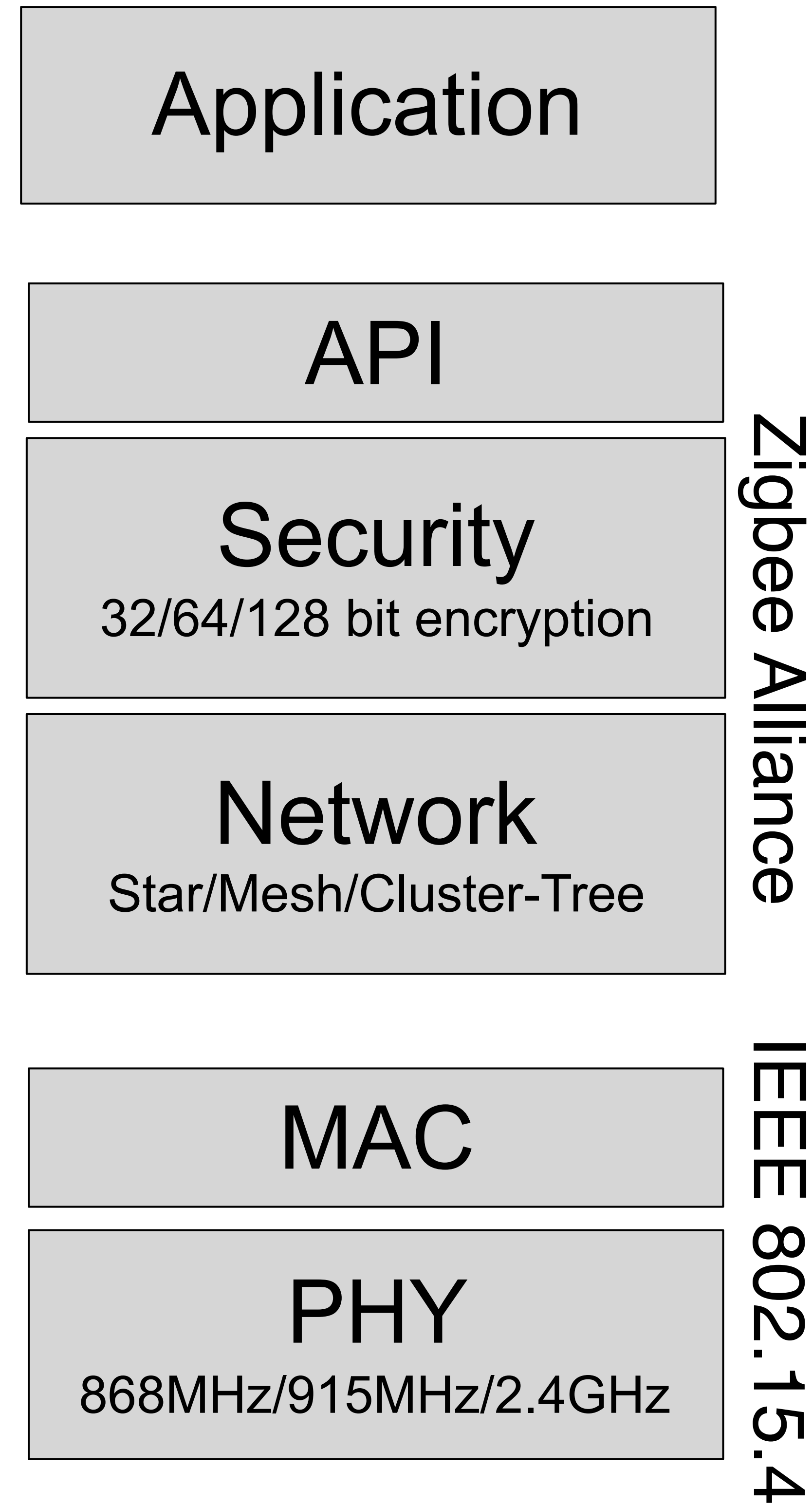
- After B has received RTS
  - B sends CTS
  - B waits some time for the data packet
  - If the data packet arrives then the process is finished
    - Otherwise B is not blocked

Details for Third Parties

- C receives RTS of A
  - waits certain time for CTS of B
- If CTS does not occur
  - C is free for own communication
- If CTS of B has been received
  - then C waits long enough such that B can receive the data packet
- D receives CTS of B
- waits long enough such that B can receive the data packet
- E receives RTS of A and CTS of B
- waits long enough such that B can receive the data packet

Zigbee

- Designed by the Zigbee alliance
  - for low power consumption embedded systems
  - provides network security
- Device Types
  - Zigbee coordinator node
    - root of network tree, bridge to other networks
  - Full function device
    - router, may be coordinator
  - Reduced function device
    - cannot relay, cheaper



Energy Informatics

05 Networks for Smart Grids

Christian Schindelhauer
Technical Faculty
Computer-Networks and Telematics
University of Freiburg