P2P Trading, Control and Communication in microgrids
IEEE Power and Energy Society
Innovative Smart Grid Techs - Industry Session
11 October 2016, Ljubljana, Slovenia.

CTTC
Centre Tecnològic de Telecomunicacions de Catalunya

innovating communications

Device to Device Comms. for the Smart Grid

M2M @CTTC

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P2P - smarTest

European Commission

ADVANTAGE
Advanced Communications and Information processing in smart grid systems

CellFive

Based on a true story…

"***Cellular Communications for Smart Grid Neighborhood Area Networks: a Survey***"

C. Kalalas, L. Thrybom, J. Alonso-Zarate

IEEE Access, April 2016

FREE OPEN ACCESS

What’s the IoT?

The End

The Fourth Industrial Revolution

1st: 1800s Industrial Revolution

2nd: 1990 The World Wide Web (www)

- *1 billion connected devices*

3rd: 2000 Mobile Internet

- *From 2 to 6 billion devices*

4th: 2020 The Internet of Things (Everything)

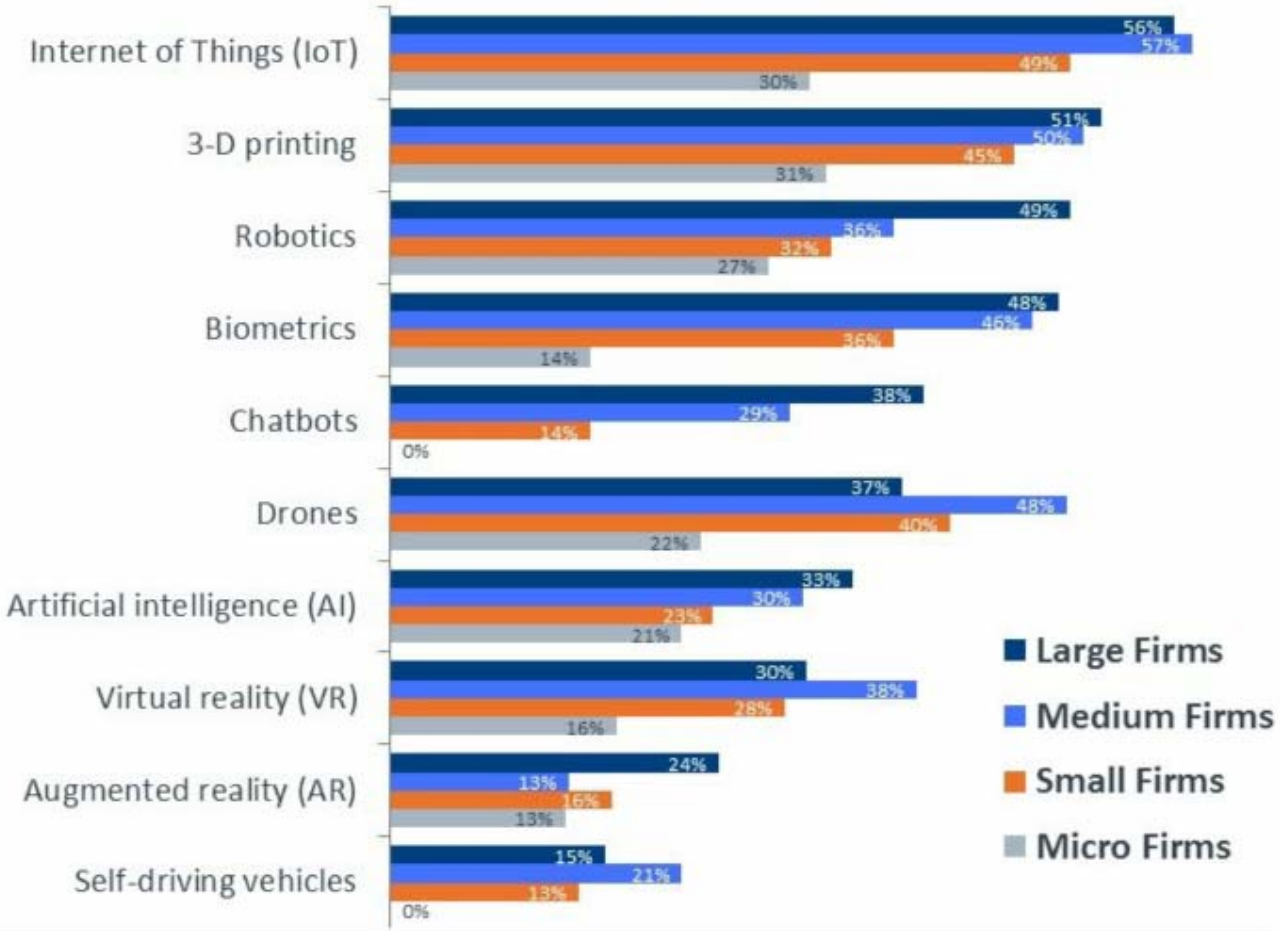
- *End of 2015: **13,4 billion** connected devices*
- *Prediction: 2020 → **38.5 billion***
- *McKinsey Global Institute (Tech Rep. 2015):*
  - *$4 trillion (2015) → $11 trillion (2025)*

Source: Juniper Research, Technical Report (2015)
http://www.juniperresearch.cpm/press/press-releases/iot-connected-devices-to-triple-to-38-bn-by-2020

Why now?

- Progress in technology makes it possible
  - Miniaturization
  - Low Cost
- We have already connected nearly every person on the planet
- Opportunity to connect lots of devices
  - Huge Market Opportunity (despite low ARPU)
- Potential
  - Enhance processes (efficiency)
  - Improve existing and create new businesses
  - Boost well-being
  - Create new jobs

Perceived Technology Impact Highly Correlated with Firm Size



CompTIA

Source: CompTIA's *Internet of Things Insights and Opportunities* study

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Key IoT Verticals

BANKING

PUBLIC SAFETY

WEARABLES

PRECISION AGRICULTURE

FUTURE DRIVING

CONNECTED HOMES

SMART GRID

TRANSPORTATION

LOGISTICS

RETAIL & VENDING

INDUSTRY 4.0

SMART CITIES

HEALTH CARE

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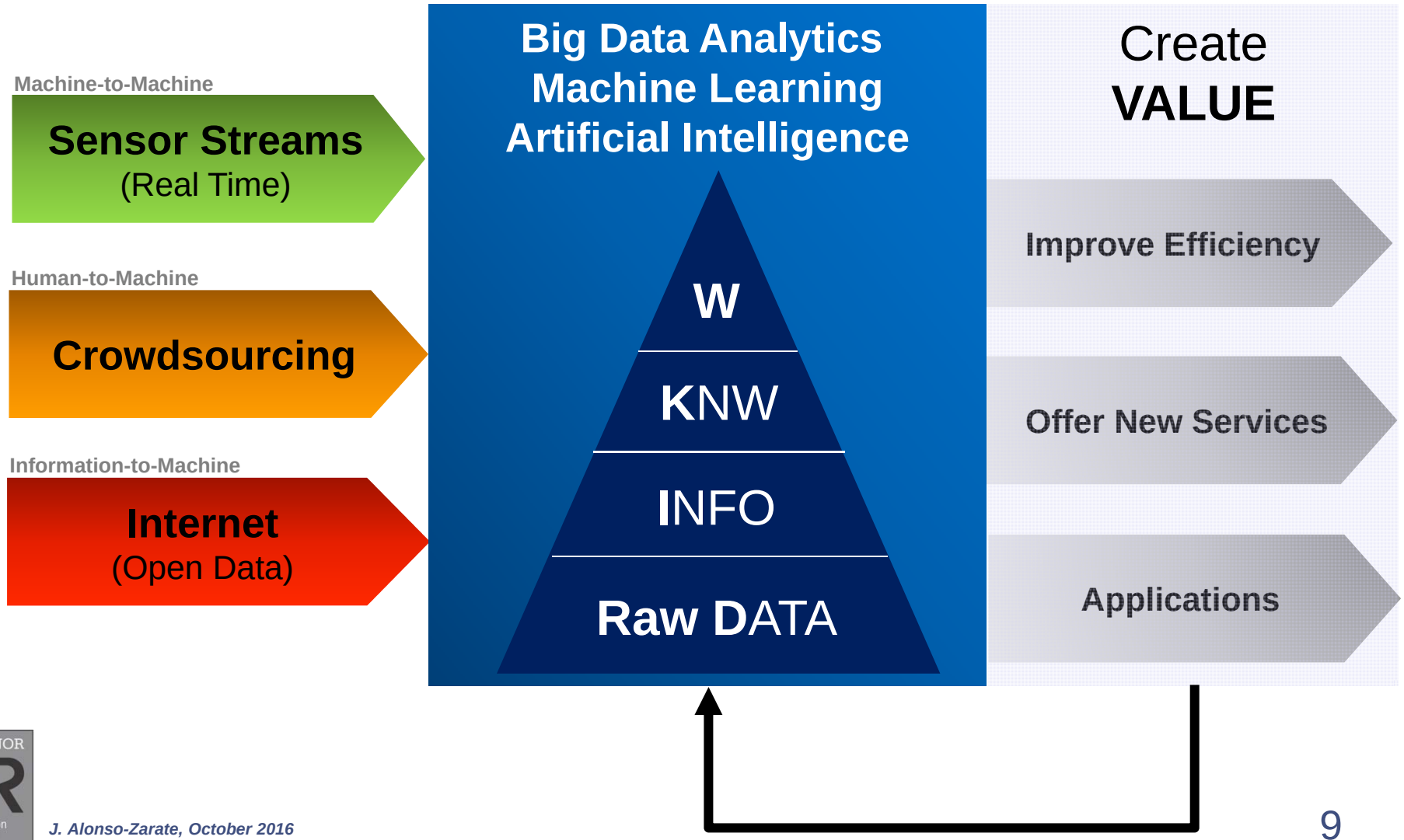
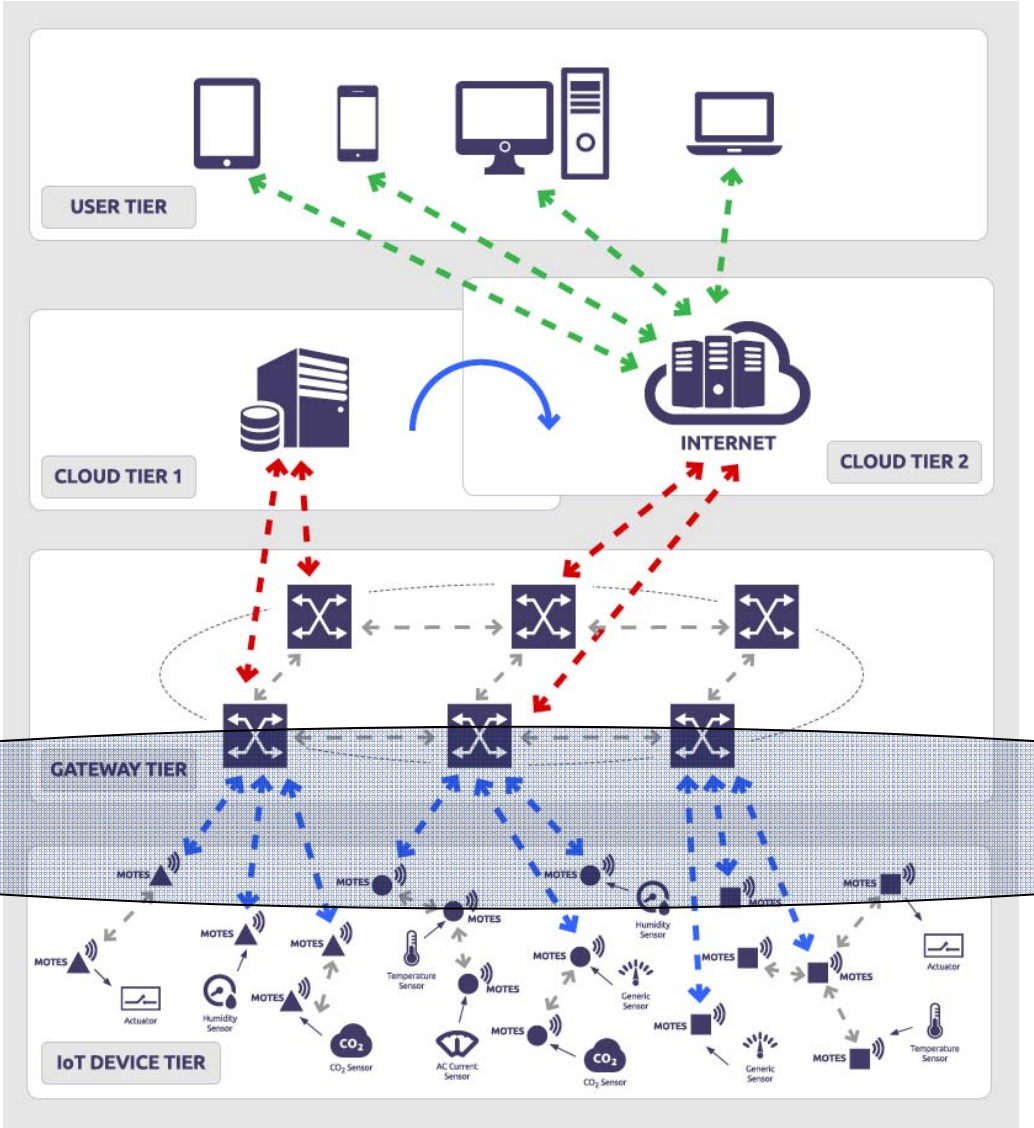
Getting value from data



Three Keys for IoT success

1. *User Acceptance*
   - ✓ *Job Destruction*
   - ✓ *Easy of use*
   - ✓ *Security*
2. *Get value from Data*
3. ***Connectivity***

Connectivity: ICT point of view



Big Data
44 ZB by 2020
44,000,000,000,000 GB

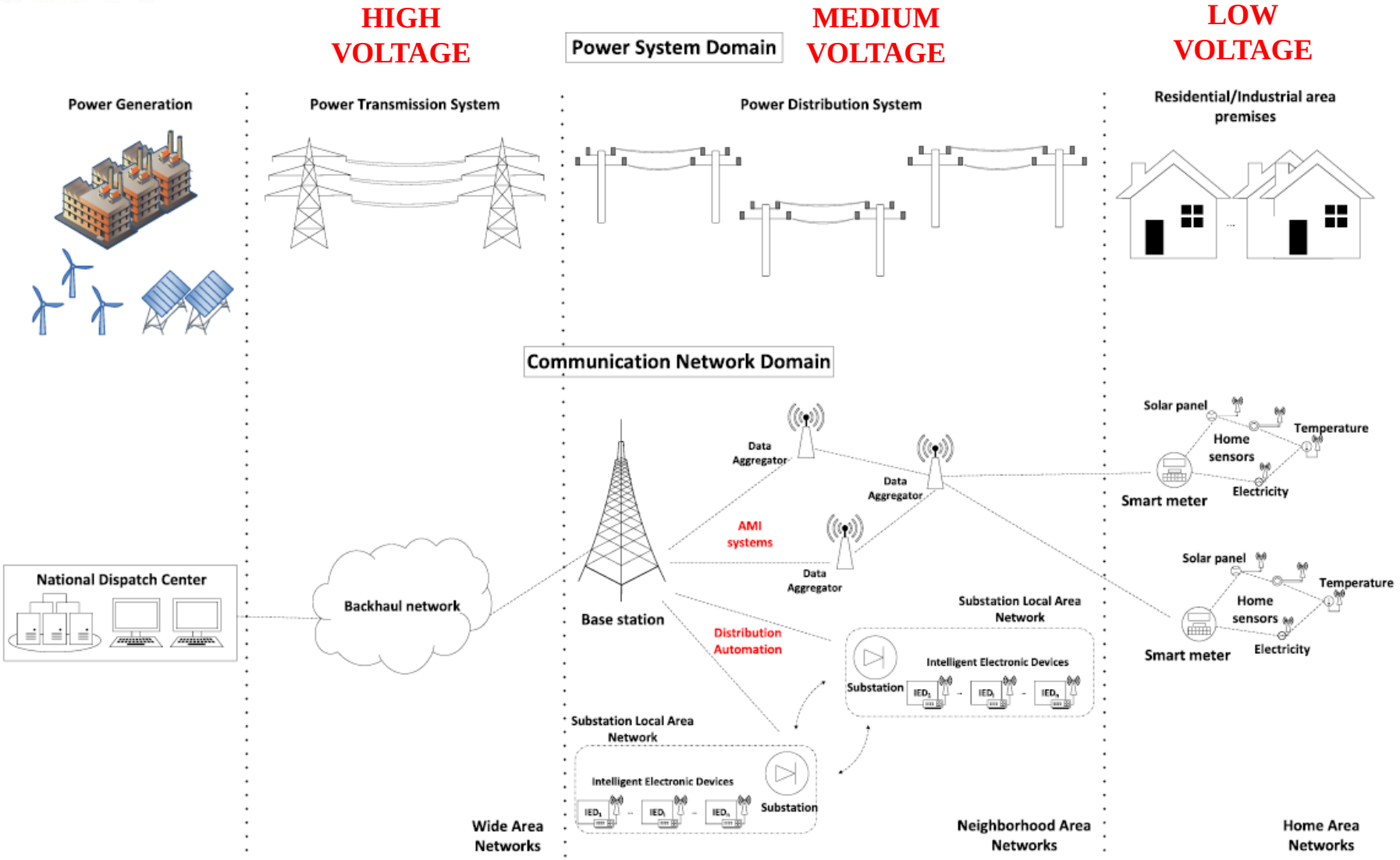
Virtualized
Core Network

Connectivity

Heterogeneous wireless techs

50 billion
by 2020

Smart Grid: the Global Picture



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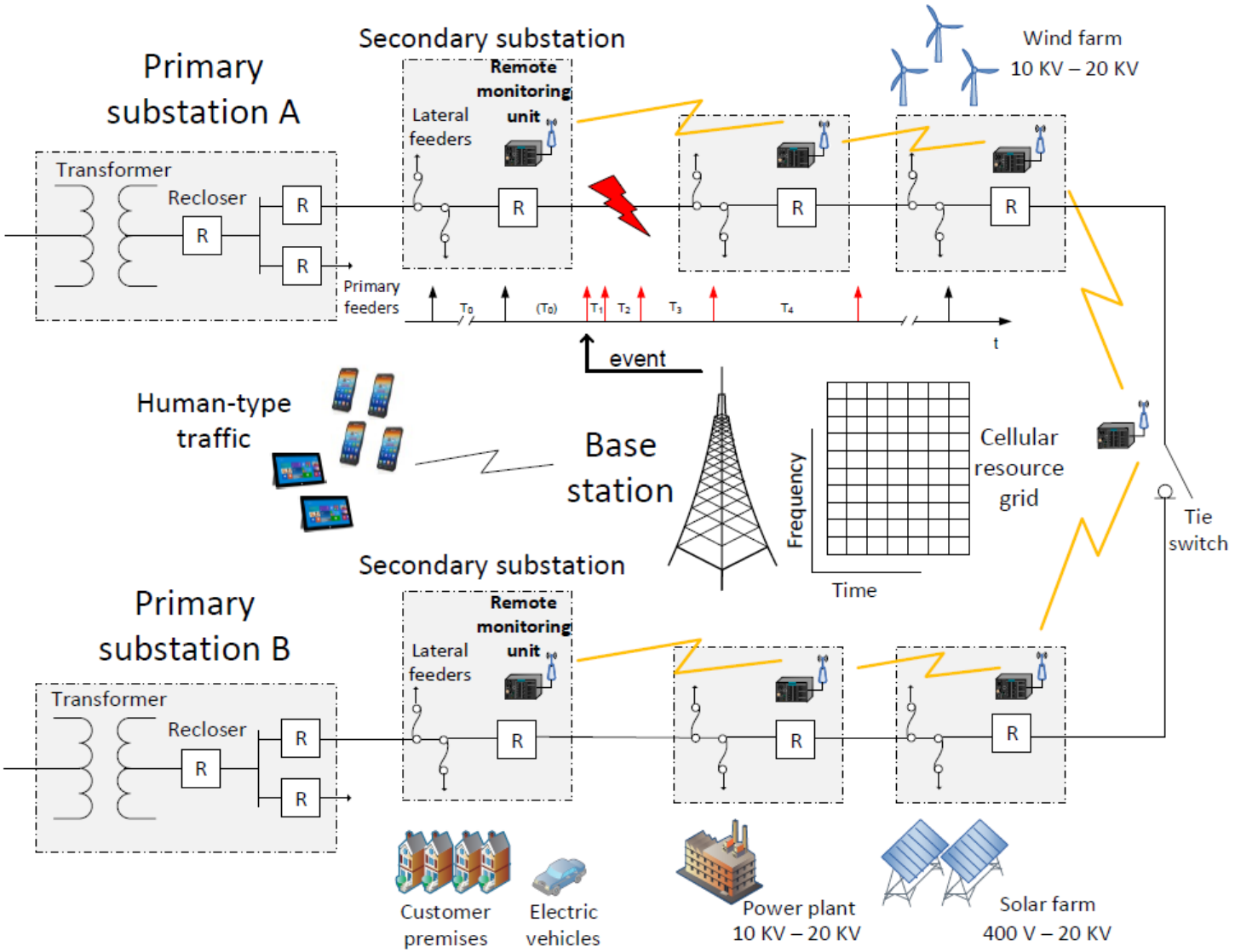
NANs at Medium Voltage



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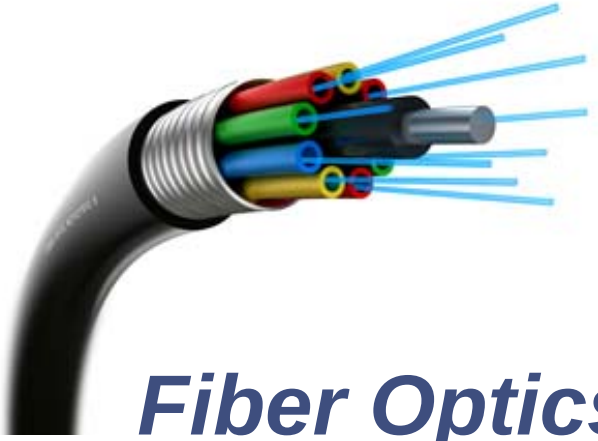
Communication Perspective

- As of today:
  - Transmission and Distribution → based on reliable **cables**
  - Consumer side → short-range **wireless** with no QoS
- New elements in the vision of the Smart Grid:
  - Distributed Energy Resources (DER) → Microgrids
  - Electric Vehicle (EV)
  - Distribution Automation (DA)
  - Automated Meter Reading (AMR)
  - P2P Energy Trading
- We need a more **flexible** and **scalable** solution
- Is ***wireless*** a feasible solution?

Wired or Wireless?

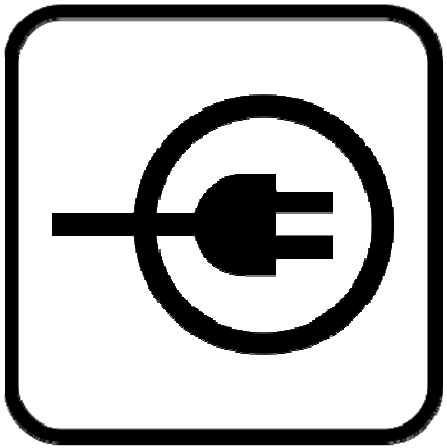
WIRED	WIRELESS
PROS	PROS
- Security - High Data Rate - High Reliability - Cost of material - Fast connection time - ***Low maintenance cost?***	- No cables - Mobility - Scalability - Flexibility
CONS	CONS → ***Challenges***
- Lack of flexibility - Scalability - Cost of deployment - No mobility - ***High maintenance cost?***	- Low Reliability (QoS) - Security (overhearing) - Lower Data rate - Interference - Connection Latency - Energy consumption - ***Total cost of ownership?***

Wired Solutions



Fiber Optics

Ethernet



Power Line Communications (PLC)

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Wireless Solutions

ZigBee Alliance

Wi Fi ™

Li Fi

NFC

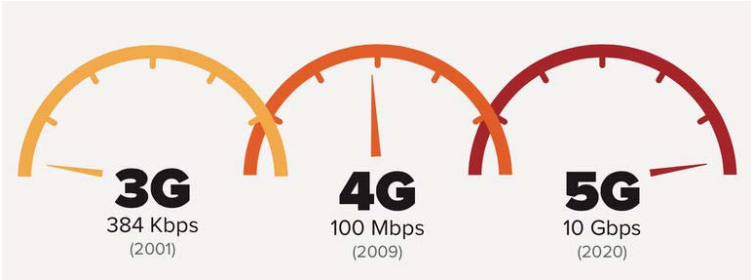
RFID

Bluetooth™ 4.

Low Energy

3GPP ™

A GLOBAL INITIATIVE



Sub-1GHz

Robustness, long range

SIGFOX

WEIGHTLESS™

LoRa™ Alliance

Wide Area Networks for IoT

INGENU simply genius

Lte ™

LTE-M

EC-GSM

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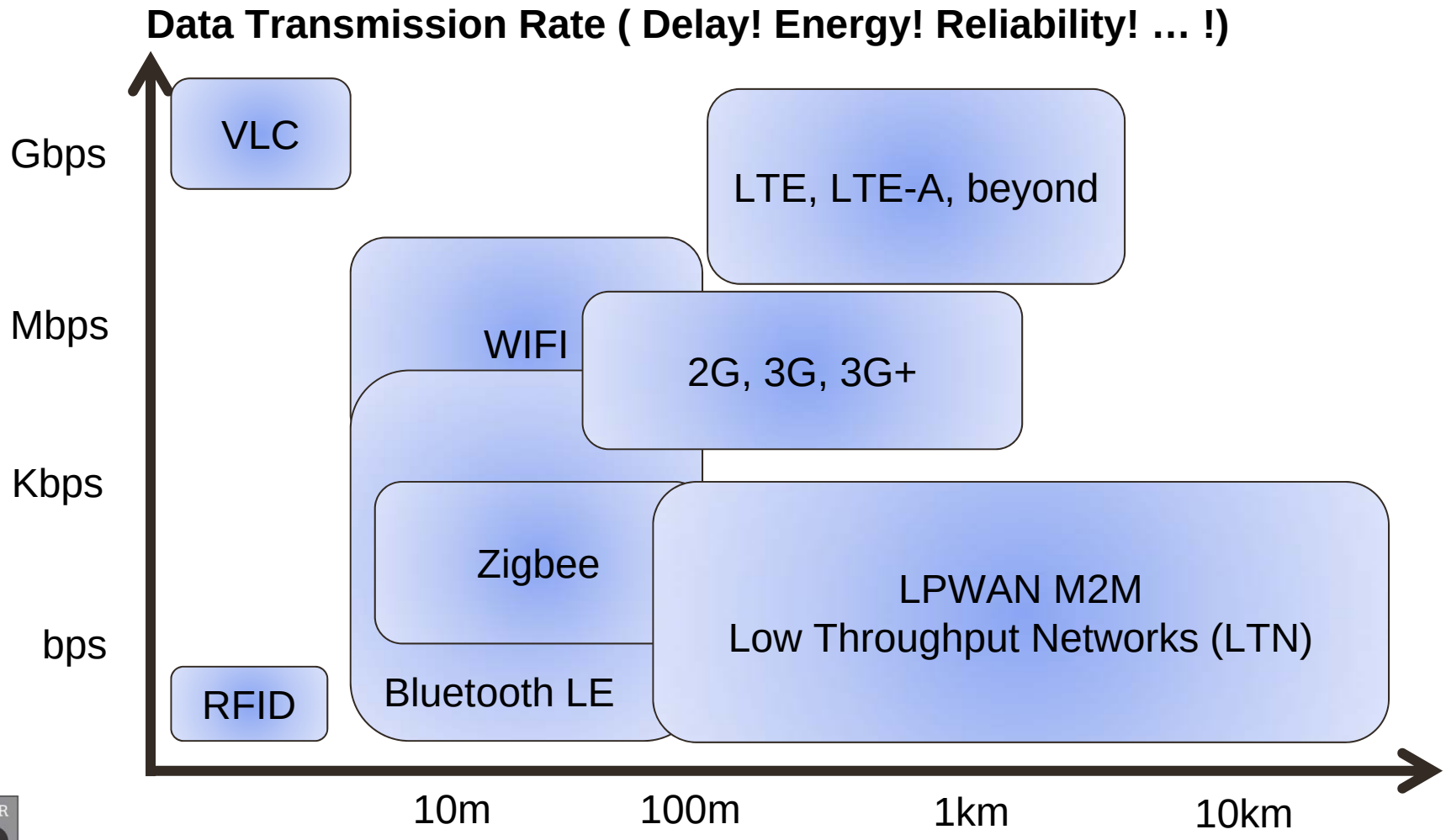
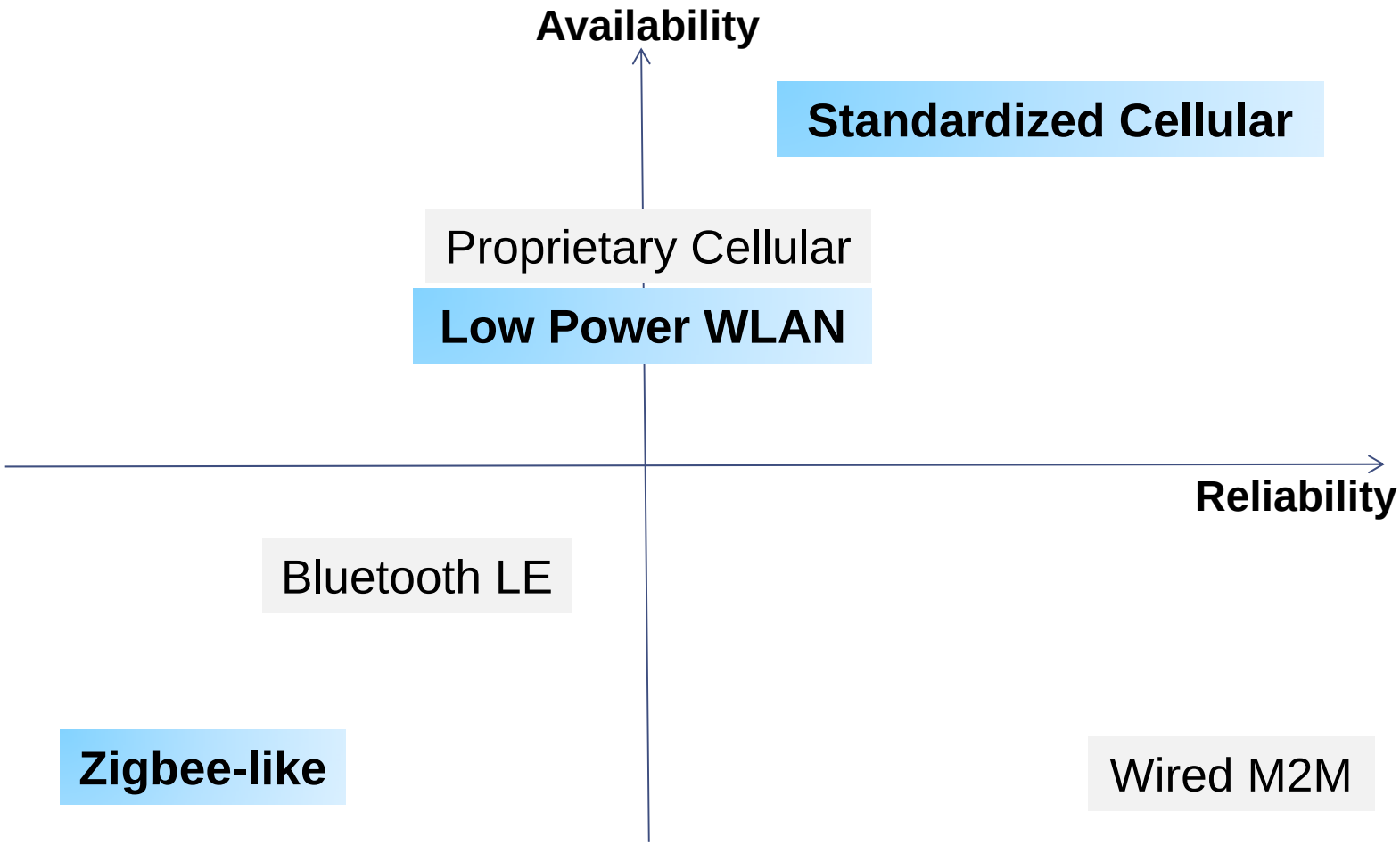
A General View (Wireless)



Selection Criteria

- Licensed **vs** Unlicensed
- **Cost**
- **Mobility** of devices
- **Latency** Requirements
- Geographical **Coverage**
- **Power and Energy** Consumption constraints
- Required **Bandwidth**
- Access to existing **infrastructure**
- **KPIs** depending on the specific application

How to select?



Availability = coverage, roaming, mobility, critical mass in rollout, etc.
Reliability = resilience to interference, throughput guarantees, low outages, etc.
(Total Cost of Ownership = CAPEX, OPEX.)

Main KPIs for Smart Grid

- Automatic Meter Reading (AMR)
  - Flexibility
  - Scalability
  - **Massive**
- Distribution Automation (DA)
  - Flexibility
  - Reliability
  - Latency
  - **Mission-Critical**

Cellular seems a right choice

- Standardized → long-term evolution / vendor support
- Licensed Frequency Bands
- **Cost is becoming lower**
- **Latency** Requirements may be meet and **guaranteed**
- Ubiquitous **Coverage**
- **Power and Energy** Consumption diminishing
- Capable of providing the required **Bandwidth**
- Already deployed **infrastructure**
- Operators offer **Service Level Agreements (SLAs)**

Limitations of cellular networks

- Not designed for Smart Grid traffic (IEC 61850-5)
- Short and Sporadic Messages
- Really **massive number of accesses**
  - RACH (Random Access Channel)
  - Congestion → Cloud RAN
- Mainly uplink data traffic
- No designed for extreme reliability → 99,9999%
- No energy optimization
- No latency optimization (delay *critical* vs delay *tolerant*)
- Little **mobility** in the smart grid

Solutions provided by 3GPP

- GPRS (**2G**) and **3G** → good but not for long term
- LTE (**4G**) → overkill design
- The future looks like:
  - LTE-M
  - EC-GSM
  - Narrow Band IoT (NB-IoT)
  - LTE-U, LTE-LAA and Integration and cooperation with WiFi
  - **5G** bringing new communication architectures
    - Device-to-Device (**D2D**) Communications

Solutions found in the literature

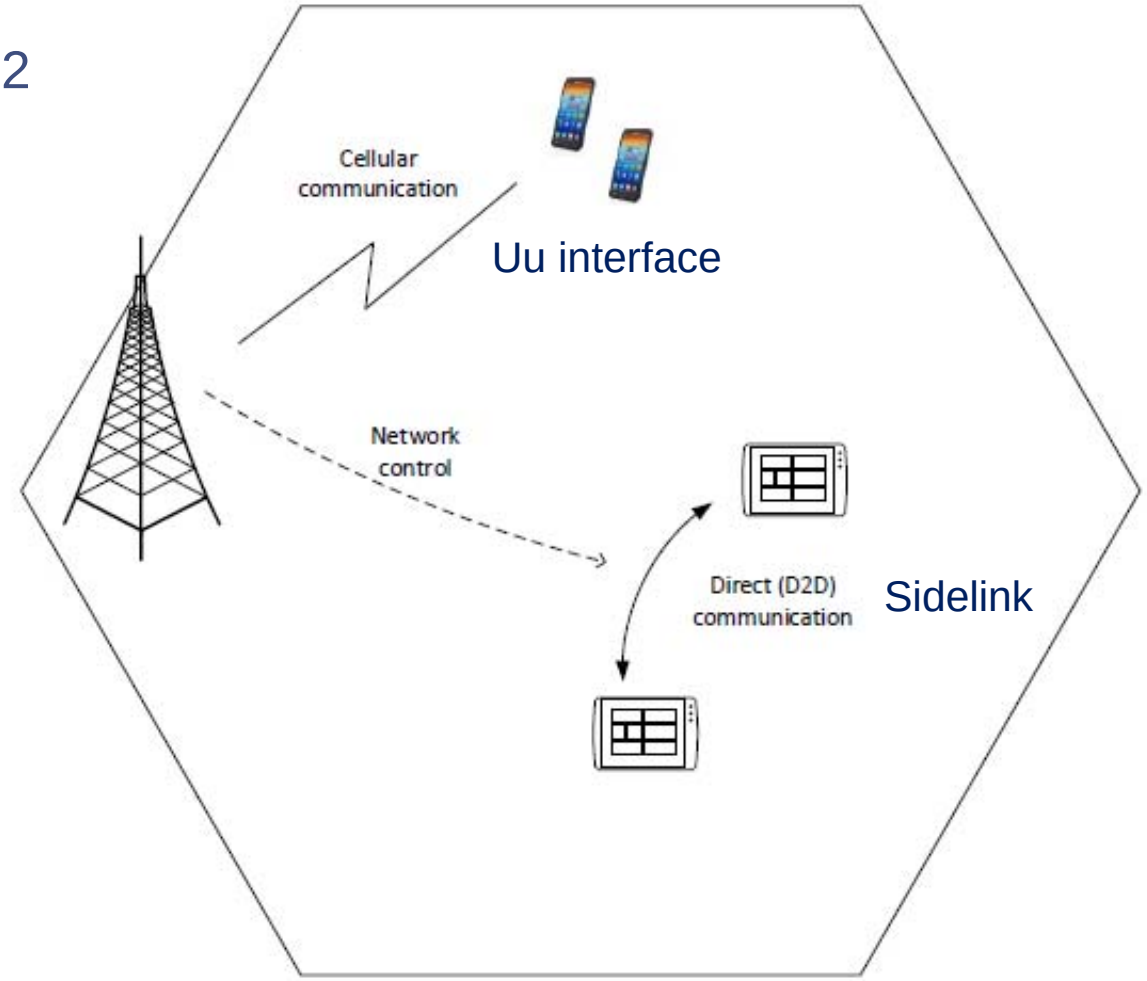
1) Improvements of LTE Radio Access → RACH
2) Scheduling algorithms (queuing policies, etc.)
3) Resource sharing strategies for MTC and HTC
4) Architectural improvements (congestion avoidance)
5) Novel communication schemes → **D2D**

Device-to-Device Communications

Introduced in Release 12

Key gains:

- Reliability
- Latency
- Energy
- Interference
- Scalability
- Network Offloading
- Capacity
- Coverage Extension



Types of D2D Communications

According to control:

- Network-controlled → Provision of SLAs
- Non-controlled → ad hoc communication, no QoS

According to use of resources:

- **Overlay** (dedicated orthogonal resources)
  - → *Key challenge*: resource partitioning
- **Underlay** (shared resources with main links)
  - → *Key challenge*: interference management

Elements of D2D Communications

1) Network discovery
2) Mode selection
3) Signaling for D2D
4) Data exchange using D2D
5) Interference Management

D2D for NANs

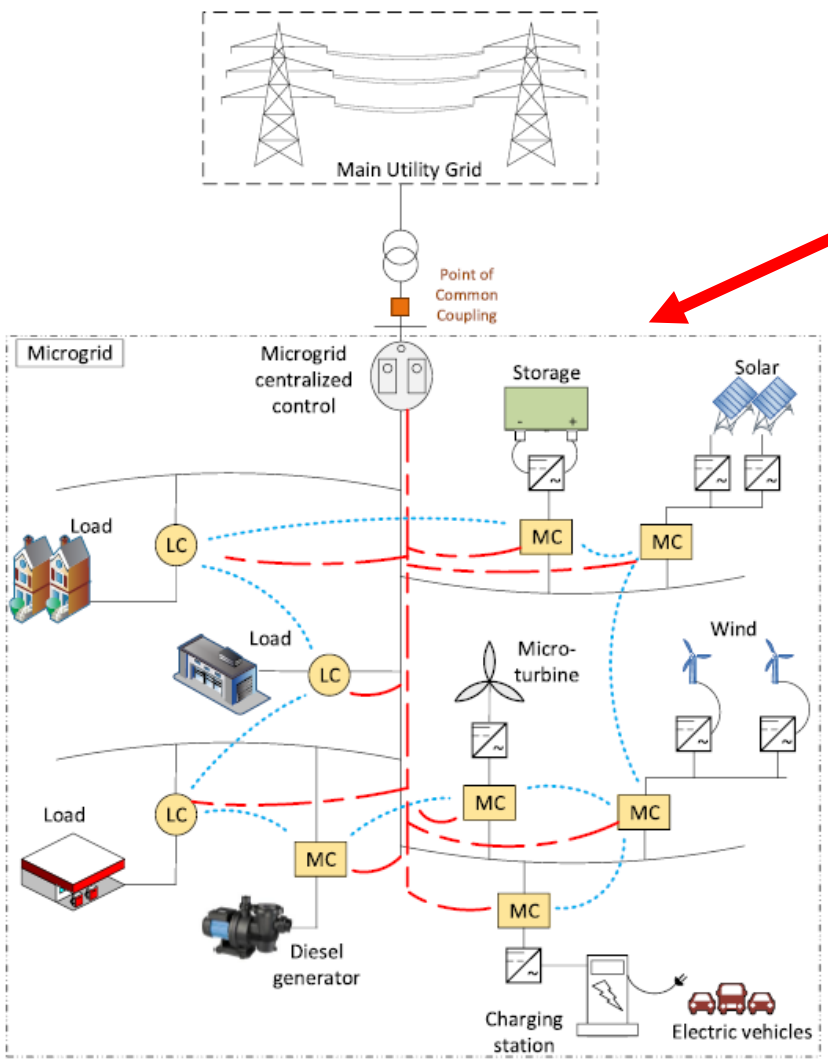
Central control → Distributed Control (Edge Computing)

Current distribution grid	Distribution grid with enhanced D2D capabilities
Radial topology with centralized power generation units and unidirectional power flows	Fully interconnected topology with DER integration and bidirectional dynamic power flows
Passive system management often requiring extensive human intervention in case of failures	Automated and intelligent system management to efficiently coordinate the diversified functions across the distributed network components
Small-scale and localized status supervision of secondary substations within their LANs	Control and real-time status monitoring of most devices, e.g., IEDs, breakers, transformers, in the secondary substations
Inter-substation communication is limited to only the adjacent substation	Support of multi-substation communications
Wide-area monitoring and control interactions related to mission-critical functions are not supported and affect reliability and power quality	Fine-grained fault detection/isolation which prevents large-scale cascading failures and drastically reduces system response times
Currently consumers have no means of receiving information that would reflect the grid state; thus cannot react to reach the balance and increase efficiency.	Consumer-interactive approach for dynamic electricity consumption and detailed pricing information (demand side management)

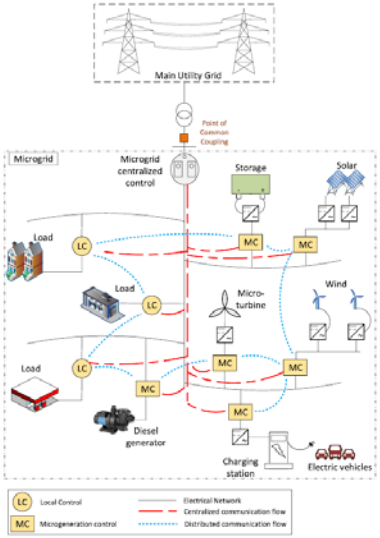
New Enabled Applications

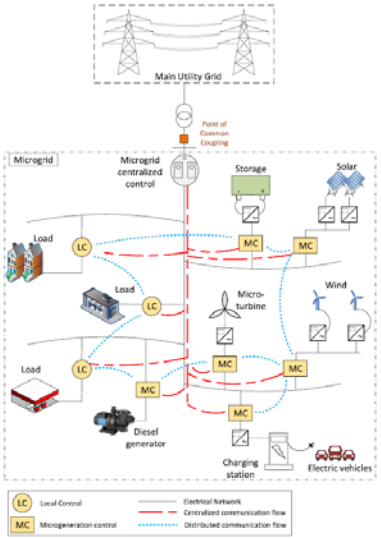
1) Integration of Microgrids and Energy Trading
2) Smart Substation Automation
3) Demand-Response

Integration of Microgrids



P2P Energy Trading





Smart Substation Automation

1) **Reliability** and **Latency** are KPIs
2) Control, Fault Detection and Protection
3) Mission-Critical Operations → **time sensitive**
4) Fast GOOSE messages among IEDs
5) Allow for inter-substation communications

Active Demand Response

1) Flexible management of energy
2) New players: *prosumers*
3) **Connection**: generators and loads
4) Pricing Signals + Heart-Beat Information
5) Discovery mechanisms
6) Energy trading → creating a market

Lessons Learned

1) Cellular Technology → good for smart grid
2) Need to be re-designed for MTC
3) Need to reduce **latency**
4) Need to increase **reliability**
5) Need to increase **scalability**
6) Need to handle **heterogeneous traffic types**

Some research challenges

- Zero-Latency → reduction of TTI, D2D Comms., RACH, RRM, etc.
- Reliability → H-ARQ, redundant transmissions, SIC, coding, etc.
- Scalability (tons of devices) → RACH, RRM, Network Coding, etc.
- Heterogeneity (applications and devices)
- Network Slicing (no single solution will work for all)
- Software Defined Networking (flexibility)
- Fog and Edge-Computing (need to accelerate processes)
- Device Management (firmware updates, etc.)
- **Security and Privacy** (many security wholes)
- Interoperability → M2M platforms, Standard API calls, etc.
- Ultra-high energy efficiency → zero-power operation is doable
- Coexistence of various radio access technologies (RATs)
- **Spectrum** flexibility → SIC, cognitive, opportunistic transmissions

D2D in P2P-Smartest

- Understanding the challenge
- Defining KPIs
- Limitations of SoA
- Design novel RACH for SmartGrid: **RADA**
  - Optimal & dynamic split of RACH resources
  - ***Redundant*** GOOSE + MMS + HTC traffic
- Mode selection based on RACH Contention
- Optimal Split of Resources (overlay D2D)

RADA Mechanism

TABLE I
SIMULATION PARAMETERS

Parameter	Value
Preambles for contention-based access	54
PRACH configuration index[5]	6
Backoff indicator[5]	20ms
Preamble duration	1ms
Maximum preamble retransmissions[5]	10
RAR window size[5]	5ms
Contention resolution timer[5]	48ms
Master information block periodicity[5]	40ms
Barring factor b	0.4
Preamble partition {HTC,MMS,GOOSE}	{13,25,16}
Traffic mix {HTC,MMS,GOOSE}	{10%, 55%, 35%}
GOOSE interarrival time[5] T_0, T_1, $T_N, N \geq 2$	0.5s, 1ms, 2^{N-1}ms

Some Results

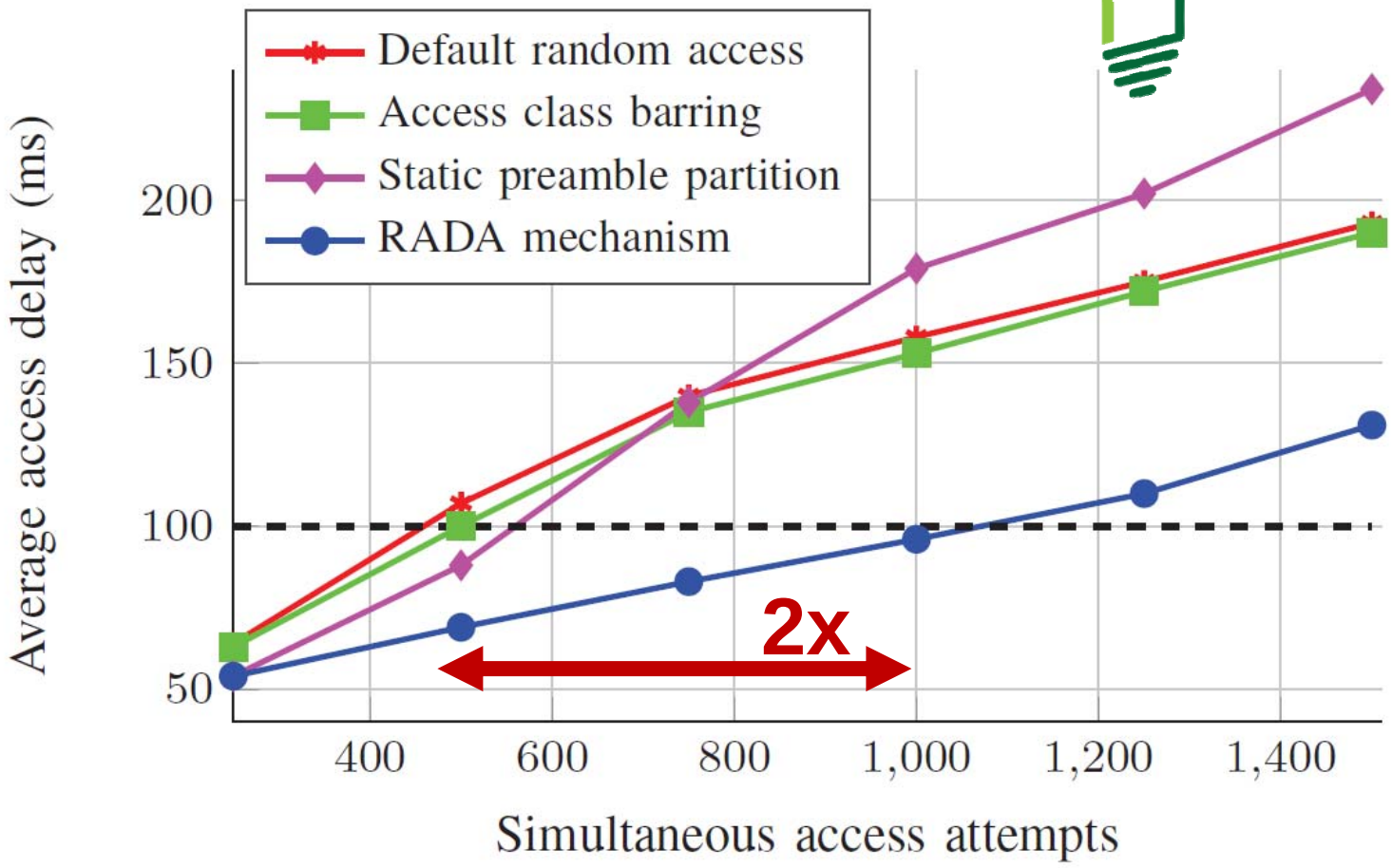


Fig. 7. Average access delay per IED (GOOSE traffic) for different random access mechanisms with increasing traffic load.

Towards a P2P-enabled Smart Grid

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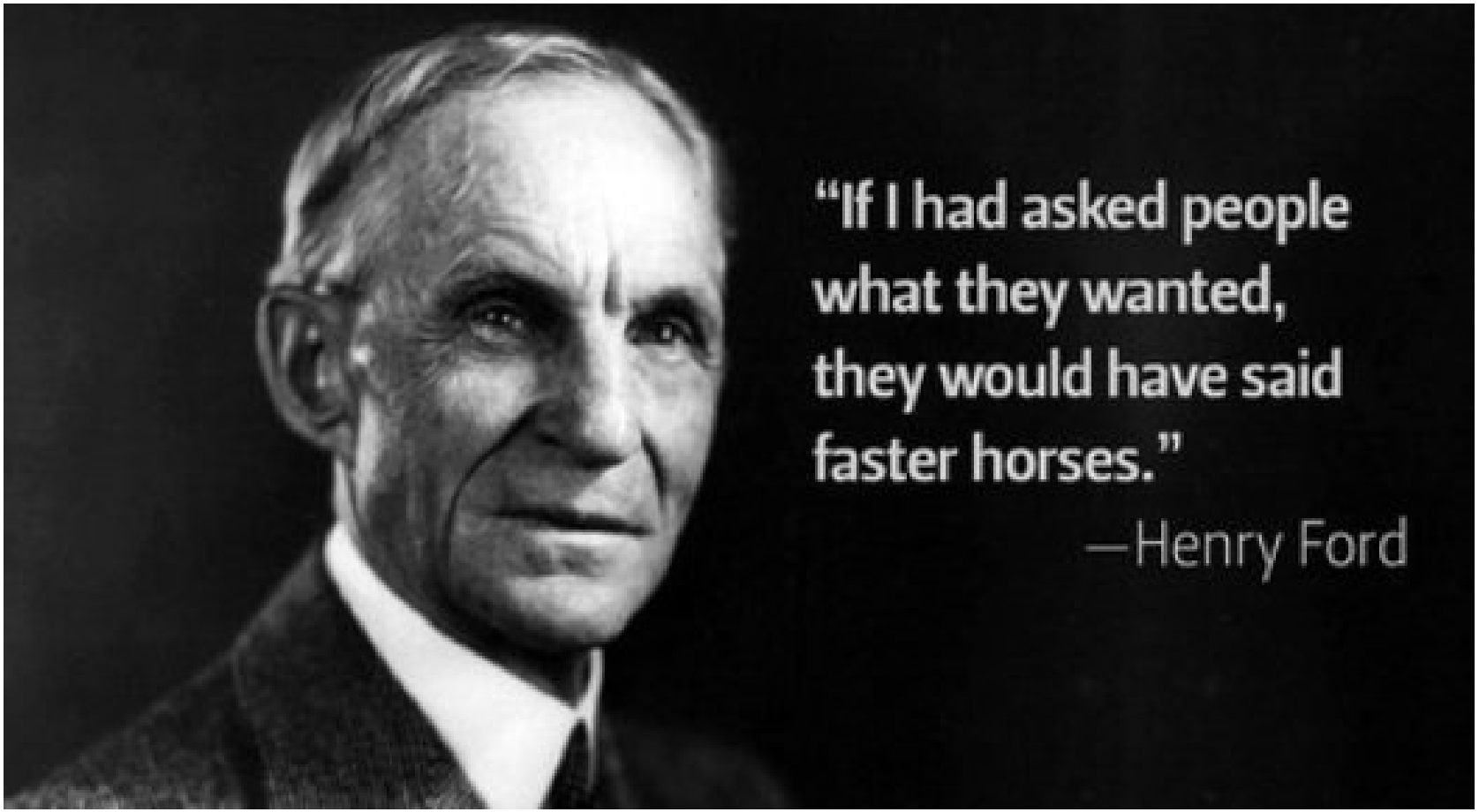
Final Take-Away Message



Thanks for your kind attention!

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