Machine-to-Machine & Sensor Technologies in Smart Cities

Vision, Standards and Applications

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Introducing Machine-to-Machine

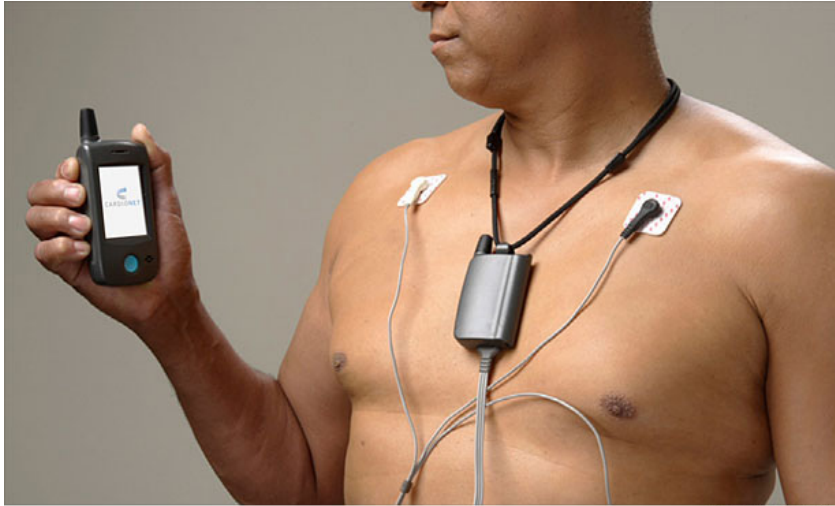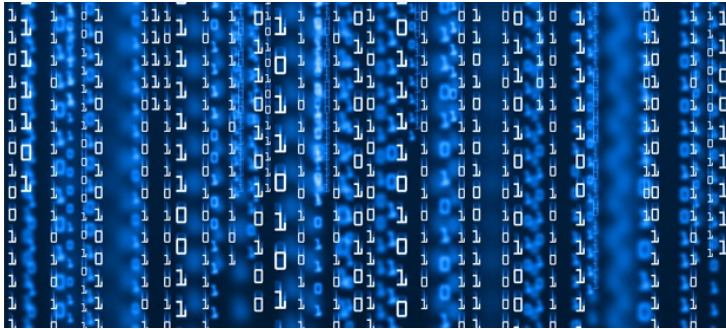# Machines Do What Humans Don't

Repetitive (Boring) Jobs	(Time) Critical Jobs

© http://japanesecanvas.blogspot.com/2010/07/bored-means-boring.html

© http://balancedlifeskills.com/home/tag/teen-stress

M2M Is All About Helping Humans

© CNN "When Machines Talk To Each Other";
http://money.cnn.com/galleries/2011/technology/1104/gallery.machine_to_machine_communication.fortune/5.html

M2M Is All About Real-Time "Big" Data

© http://www.zdnet.com/big-data-all-you-need-to-know-1339335818/

RMG#456
rail-mounted gantry serial no. 019567 38990033

Operation Mode:
OFF · ON · STANDBY

current yard traffic
MED · HEAVY

shipment portion
20' UNLOADED · LOADED
40'

http://strata.oreilly.com/2012/01/what-is-big-data.html

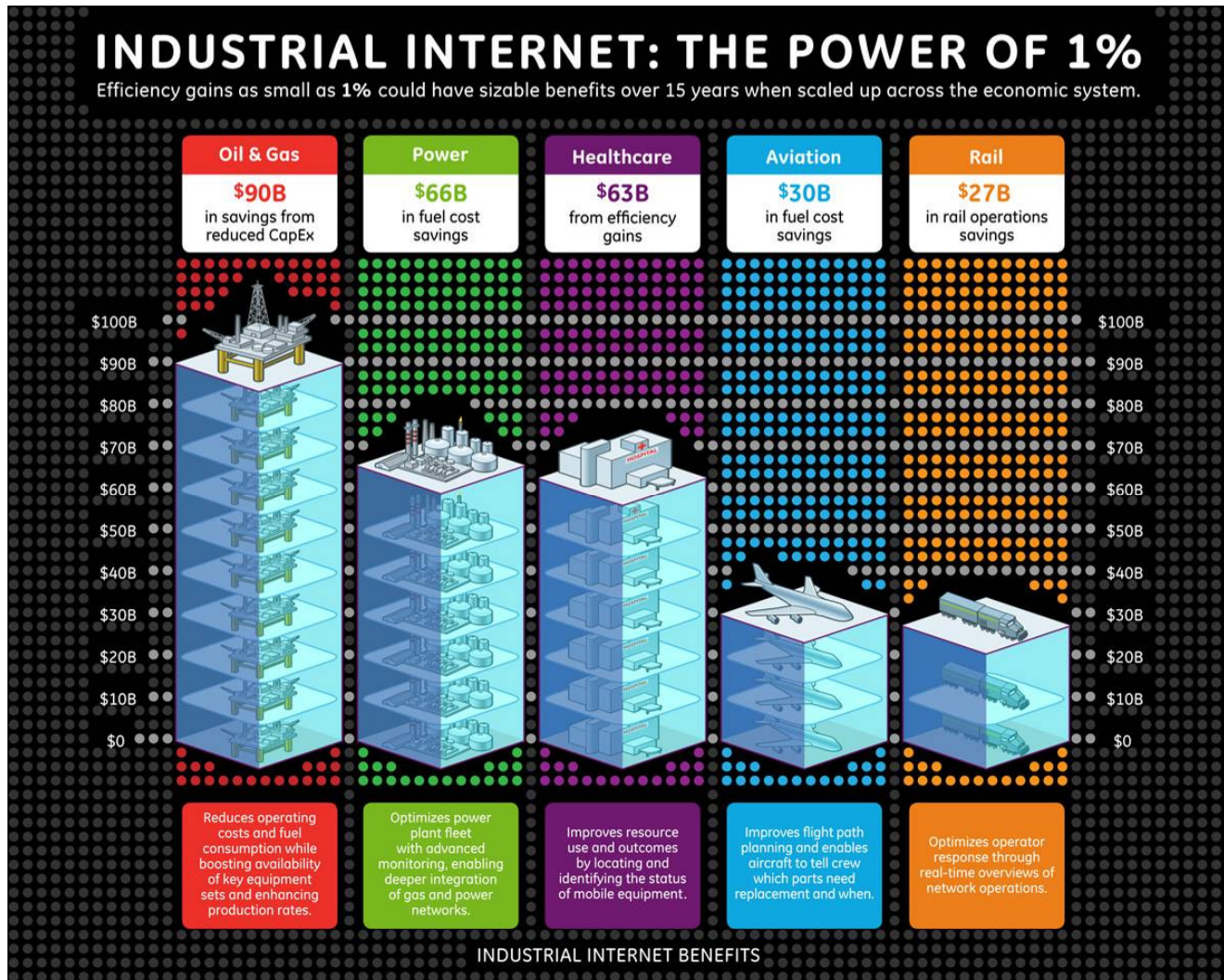http://tinyurl.com/bro8y8u

http://tinyurl.com/dyu2ncs

M2M Is All About Opportunities

http://www.gereports.com/new_industrial_internet_service_
technologies_from_ge_could_eliminate_150_billion_in_waste/

6

Upstream Data Flow

Instrumented + **Interconnected** + **Intelligence** = **Smarter Data**
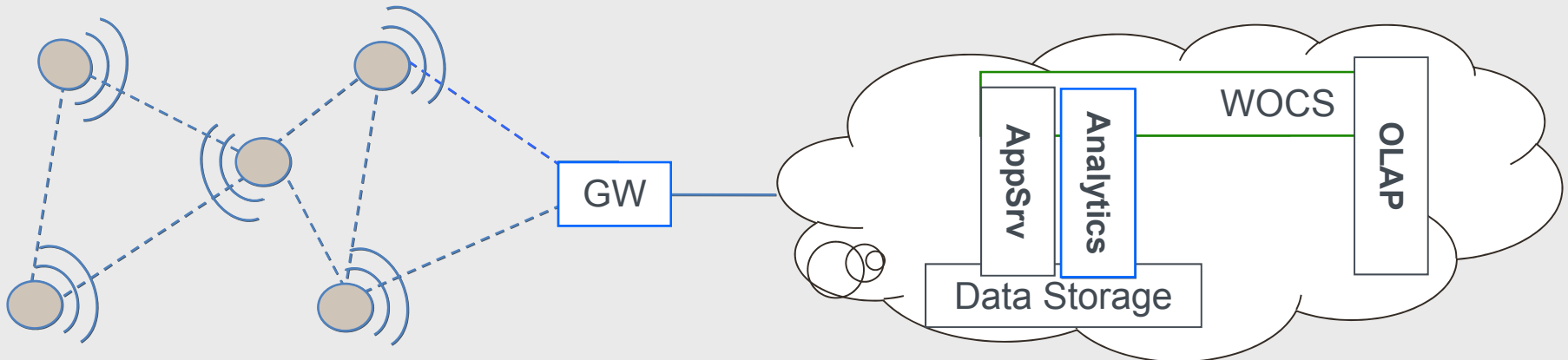
embedded computing + network computing + cloud computing = reliable real-time & statistical data

GW

WOCS

AppSrv | Analytics | OLAP

Data Storage

sensor (efficiency)	network (reliability)	gateway (availability)

LOW POWER NETWORK

cloud (ubiquitous)	data (scalable)	storage (availability)

BIG DATA HANDLING

Downstream Data Flow

Intelligent Data	+	Front-Ends	+	Panels	=	Real-Time News

business intelligence	+	corporate view	+	crowd view	=	unprecedented client experience

AppSrv · Analytics · Data Storage · WOCS · IPR · OLAP
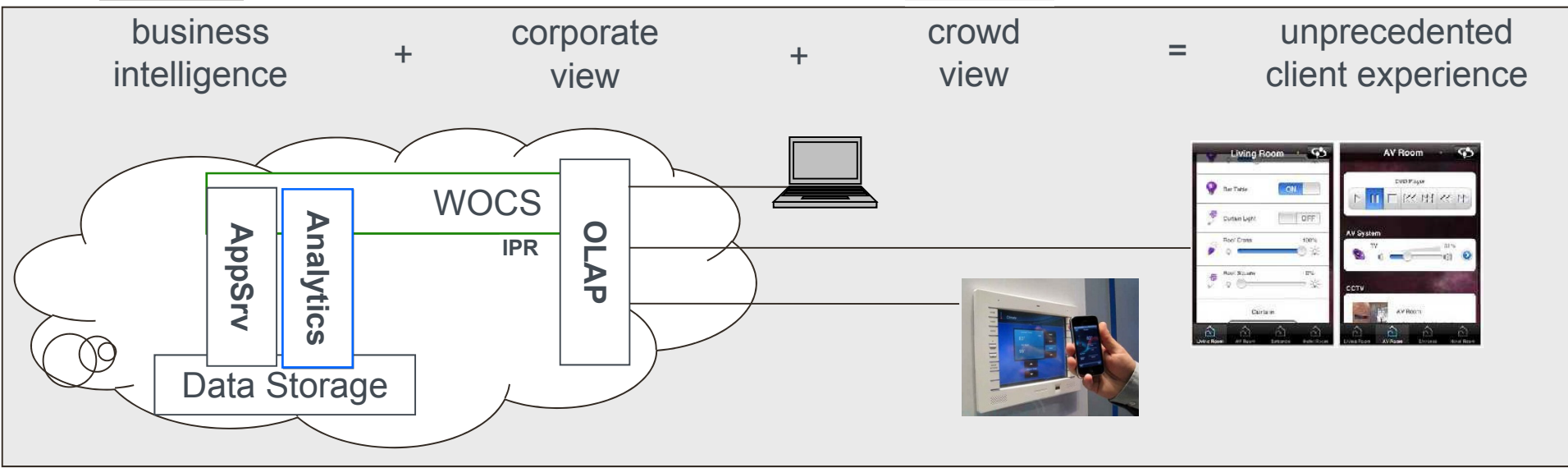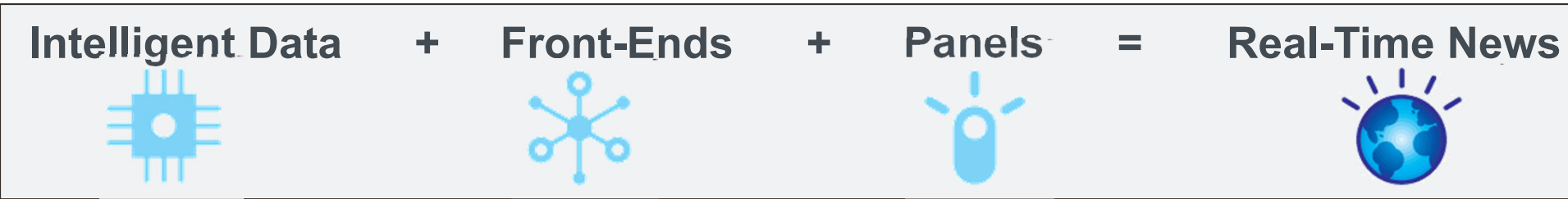
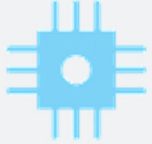| application (secure)	processing (intelligent)	interface (scalable)	computer (ubiquitous)	mobile (reachable)	infrastructure (reliable)

BIG DATA INTELLIGENCE   **VISUAL FRONT-ENDs**

Data Mashup Platforms

Real-Time **+** **Crowdsourced** **+** **Open Data** **=** **Smart Applications**

Machine-to-Machine

Sensor Streams

Human-to-Machine

Crowdsourcing

Information-to-Machine

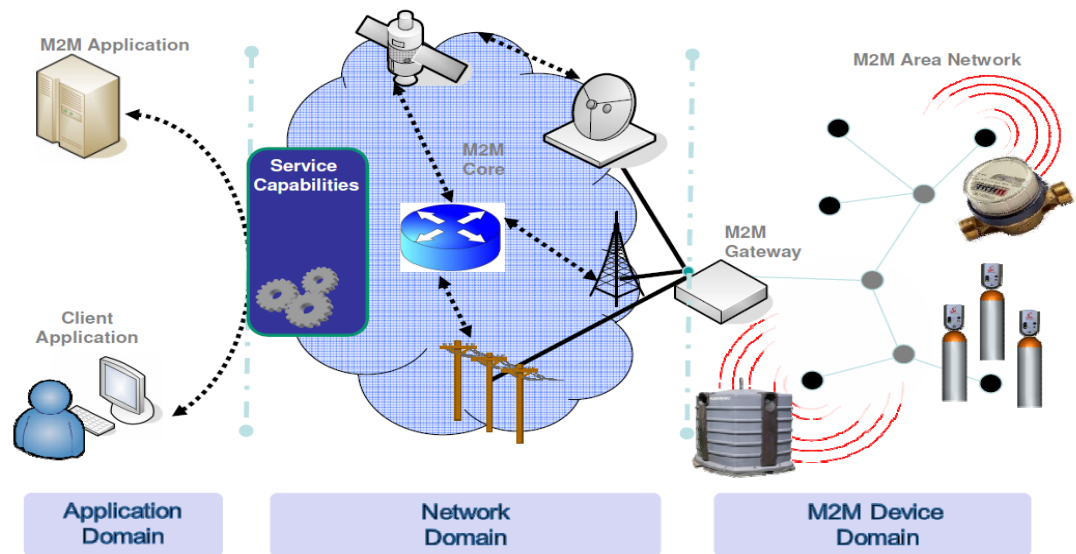**Internet**

"Big Data" Analytics

Improve Efficiency

Offer New Services

Power Applications

Tough Technical Implications

- **Machine-to-Machine (M2M) means no human intervention whilst devices are communicating end-to-end.**

- This assumes some fundamental M2M system characteristics:
  - support of a **huge amount** of nodes, sending **small data each**
  - **mission-critical** data provision
  - **autonomous** operation
  - self-organization
  - power efficiency
  - reliability
  - etc, etc

M2M Application

Client Application

Service Capabilities

M2M Core

M2M Gateway

M2M Area Network

Application Domain

Network Domain

M2M Device Domain

© ETSI

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Technical Overview of Machine-to-Machine

Quick Intro

- **Machine** – To – Machine:
  - device (water meter) which is monitored by means of sensor [in "uplink"]
  - device (valve) which is instructed to actuate [in "downlink"]
  - keywords: physical sensors and actuators; cost

- Machine – **To** – Machine:
  - network which facilitates end-to-end connectivity between machines
  - composed of radio, access network, gateway, core network, backend server
  - keywords: hardware; protocols; end-to-end delay and reliability; cost

- Machine – To – **Machine**:
  - device (computer) which extracts, processes (and displays) gathered information
  - device (computer) which automatically controls and instructs other machines
 - keywords: middleware, software, application; cost

M2M End-to-End Network

- **Access Network** – connecting the sensors & actuators:
  - "wired" (cable, xDSL, PLC, optical, etc.)
  - wireless "capillary"/short-range (WLAN, ZigBee, IEEE 802.15.4x, etc.)
  - wireless cellular (GSM, GPRS, EDGE, 3G, LTE-M, WiMAX, etc.)
- **Gateway** – connecting access and backhaul/core networks:
  - network address translation
  - packet (de)fragmentation; etc.
- **Core/Backend/Internet Network** – connecting to computer system:
  - IPv6-enabled Internet

MACHINE · NETWORK · MACHINE

WATER PIPE — VALVE — METER — ACCESS NETWORK — GATEWAY — CORE NETWORK
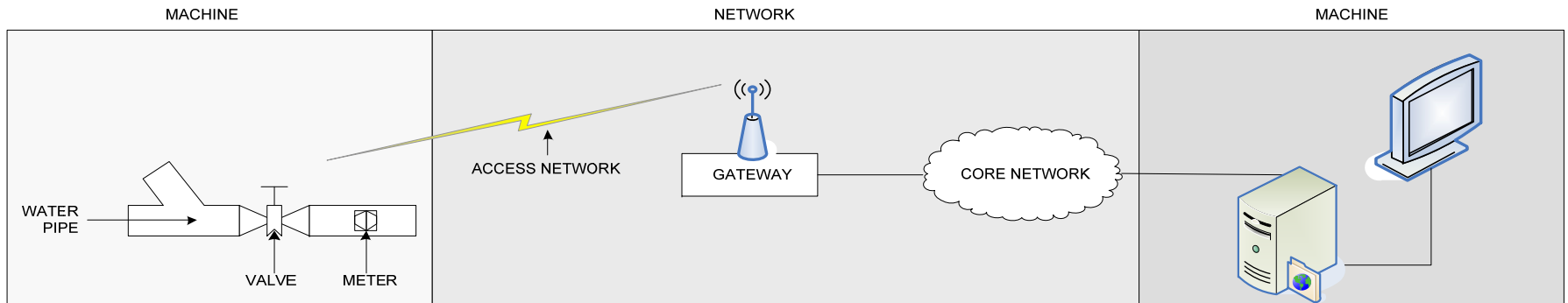
M2M Access Networks [1/2]

■ Connecting your smart meters through 4 example access methods:
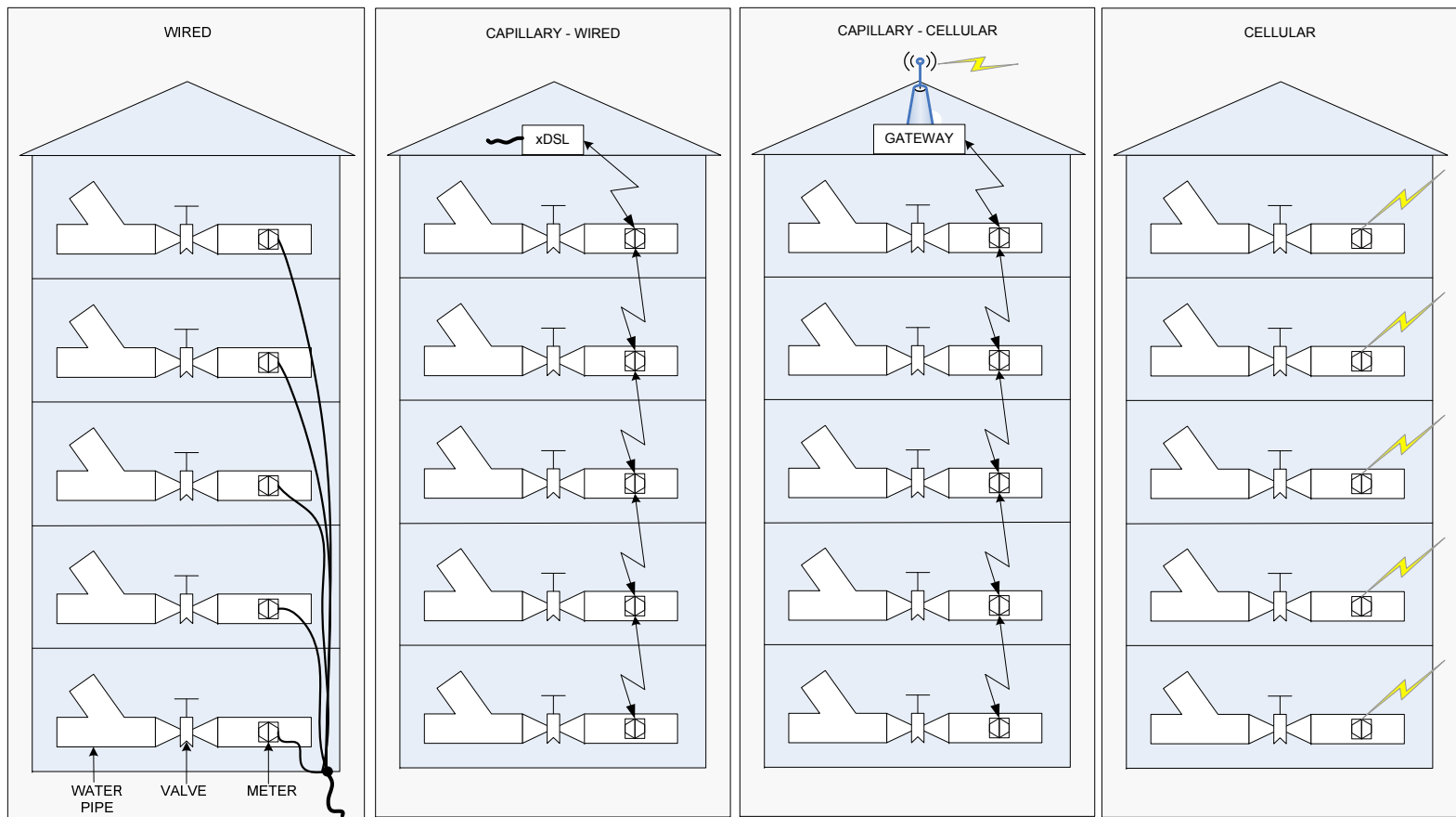
M2M Access Networks [2/2]

- **Wired Solution** – dedicated cabling between sensor - gateway:
  - pros: very, very *reliable*; very high rates, little delay, secure
  - cons: very *expensive to roll out*, *vandalism*, *not scalable*, *no mobility*

- **Wireless Capillary Solution** – shared short-range link/network:
  - pros: *cheap* to roll out, generally scalable, *low power*
  - cons: short range, *multi-hop not a solution*, low rates, weaker security, *interference*

- **Wireless Cellular Solution** – dedicated cellular link:
  - pros: *excellent coverage*, mobility, *roaming*, generally secure, infrastructure
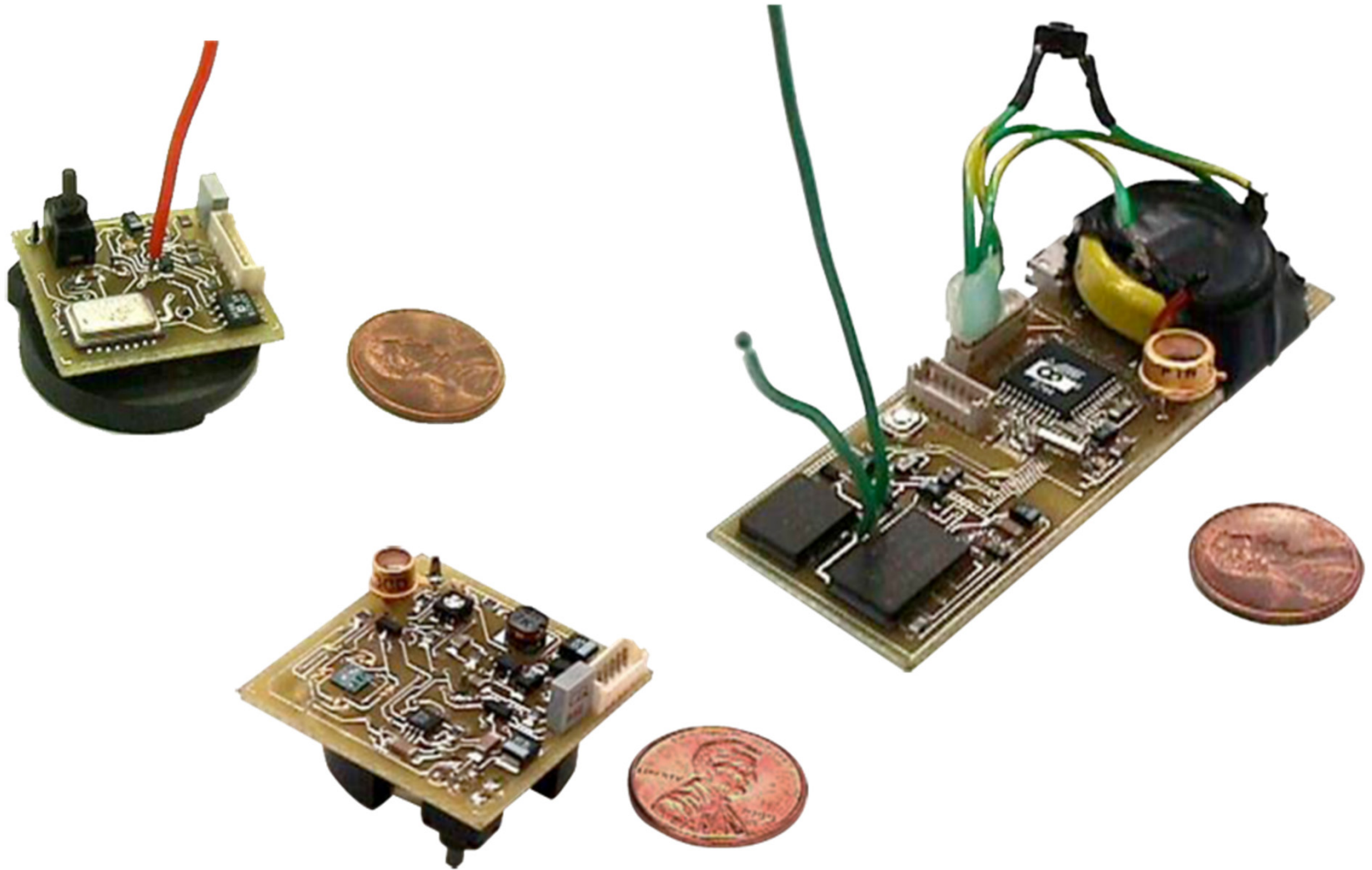 - cons: *expensive operate*, not cheap to maintain, *not power efficient*, delays

Novelty of Wireless M2M
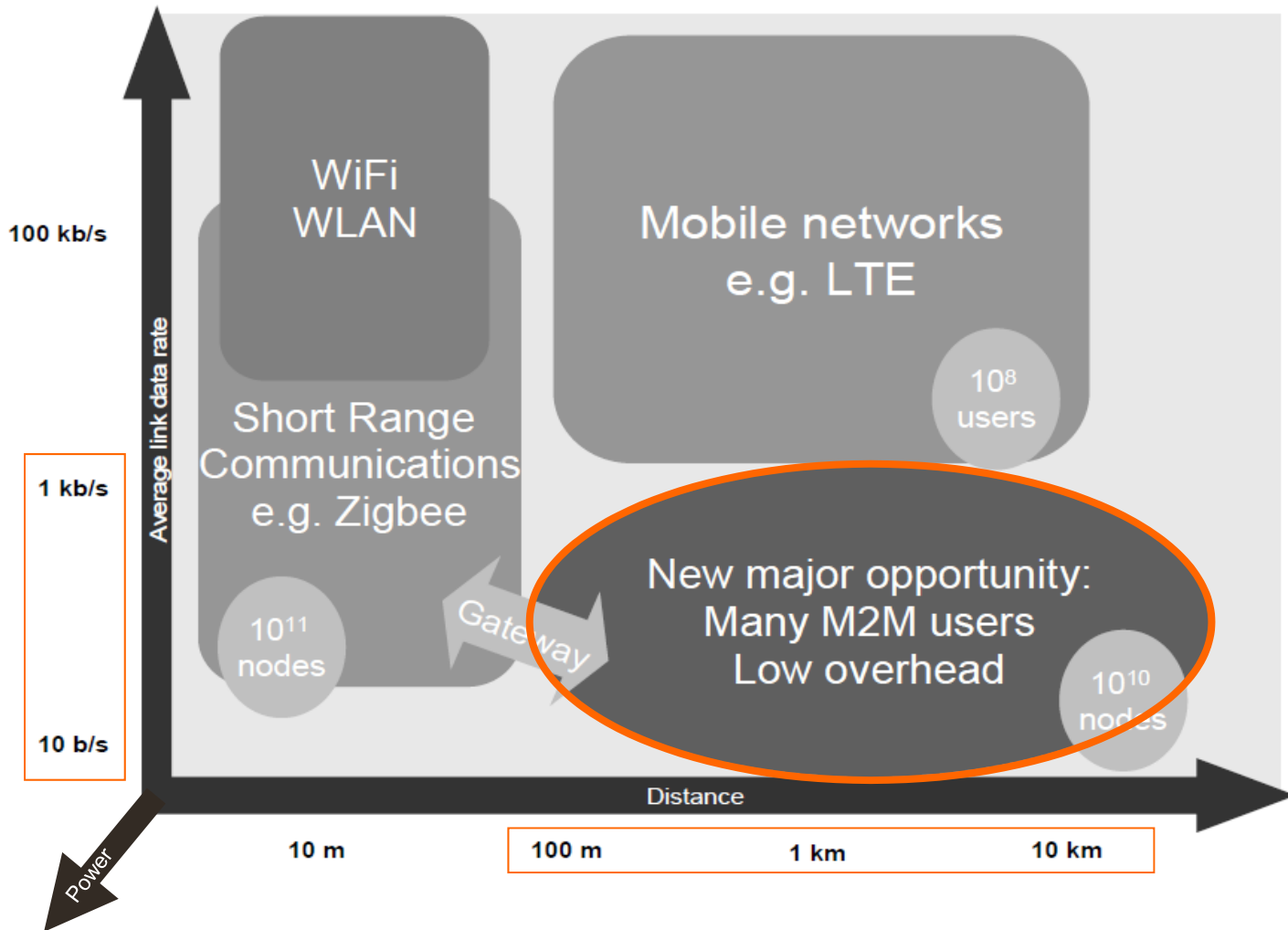
3

Capillary M2M Technologies

Off-The-Shelf Hardware – Today

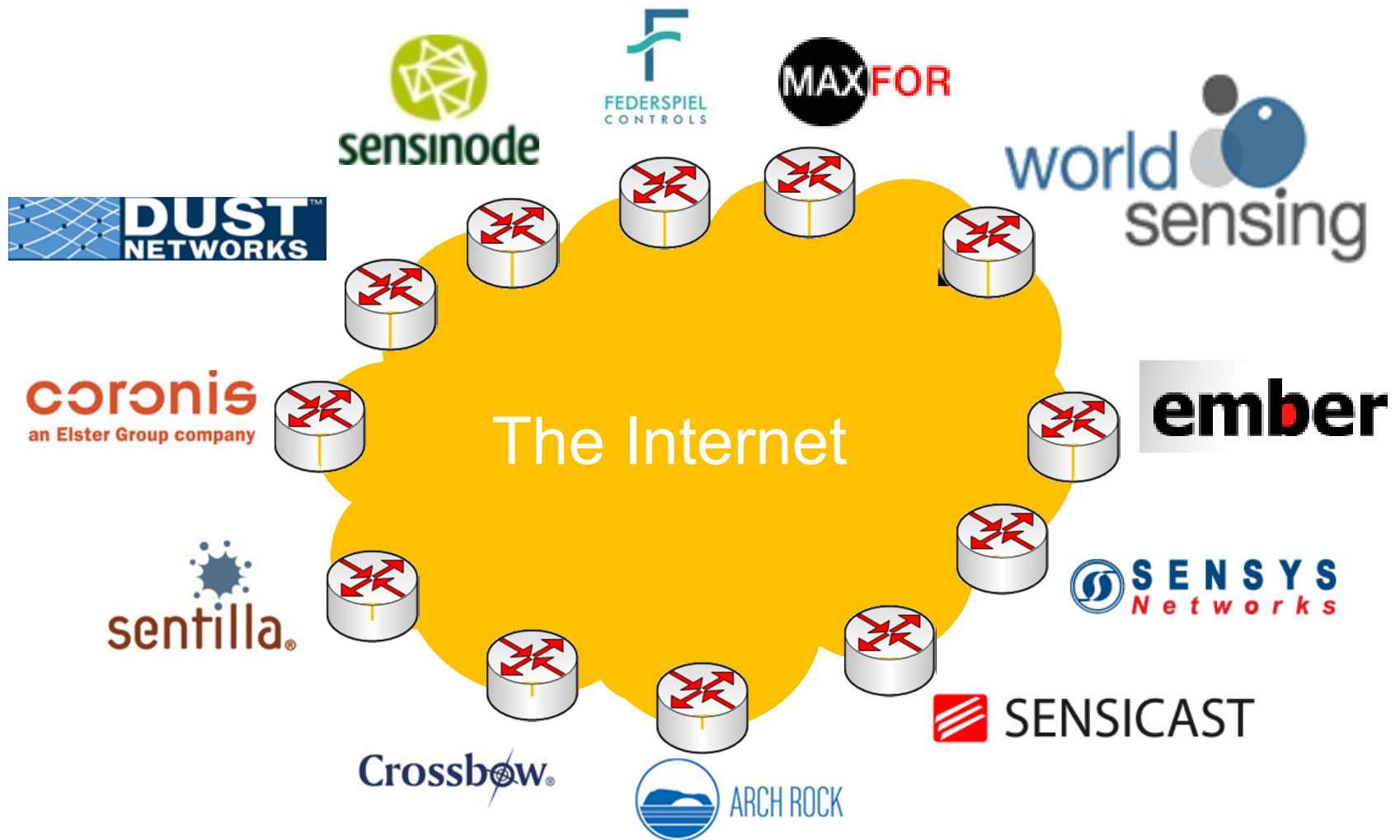# Challenge #1: Interference

868 MHz

433 MHz

2.4 GHz

5 GHz

WiFi™
IEEE802.11b/g/n

WiFi™
IEEE802.11a/n

Bluetooth®

wibree

Z-wave the wireless language

io homecontrol®

wavenis more than wireless

ZigBee® Alliance
Wireless Control That Simply Works

IEEE802.15.4

nanotron TECHNOLOGIES

Challenge #2: Standards

Standardized Capillary M2M Stack

		Zigbee-like	**Low-Power Wifi**
IETF	**Application**	IETF CORE	HTTP, etc
	Transport	(Lightweight TCP), UDP	TCP, UDP, etc
	Networking	IETF ROLL (routing)	IPv4/6, etc
		IETF 6LoWPAN (adapt.)	
IEEE	**MAC**	IEEE 802.15.4e	IEEE 802.11
	PHY	IEEE 802.15.4-2006	

Advantages of Low-Power WiFi

Ubiquitous Infrastructure

2bn Wifi Devices

Vibrant Standard

IEEE 802.11™

300 members   Wi Fi

Interference Management

NAV Medium Reservation

Sound Security

WPA2/PSK/TLS/SSL

LP Wifi vs ZigBee Capillary M2M

6LoWPAN vs. Low-power Wi-Fi at 54Mbps

	6LoWPAN		Low-power Wi-Fi	
Packet size	8 Bytes	1024 Bytes	8 Bytes	1024 Bytes
Time (ms)	6	23.61	11.3	16.58
Energy (mJ)	2.5	9.17	0.55	1.28

10x

"Low-power Wi-Fi provides a significant improvement over typical Wi-Fi on both latency and energy consumption counts."

"LP-Wifi consumes approx the same as 6LoWPAN for small packets but is much better for large packets."

[© IEEE, from "Feasibility of Wi-Fi Enabled Sensors for Internet of Things," by Serbulent Tozlu
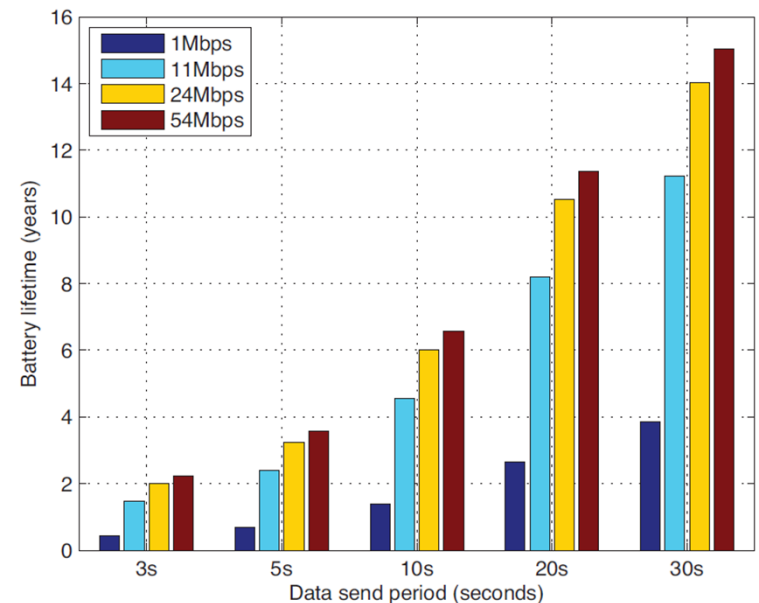
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Cellular M2M Technologies

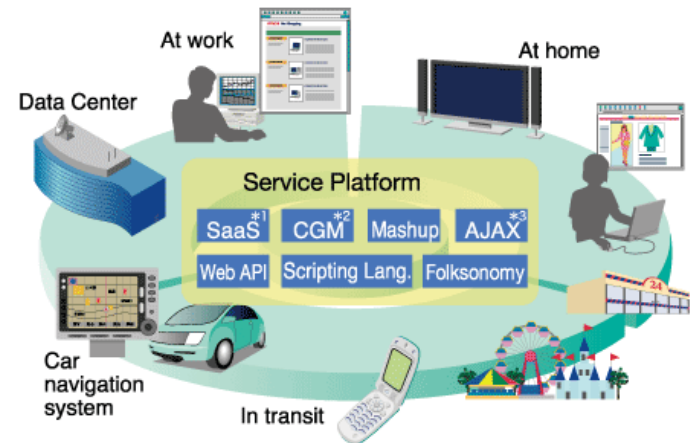# Advantages of Cellular M2M

Ubiquitous Coverage

Mobility & Roaming

Interference Control

Service Platforms
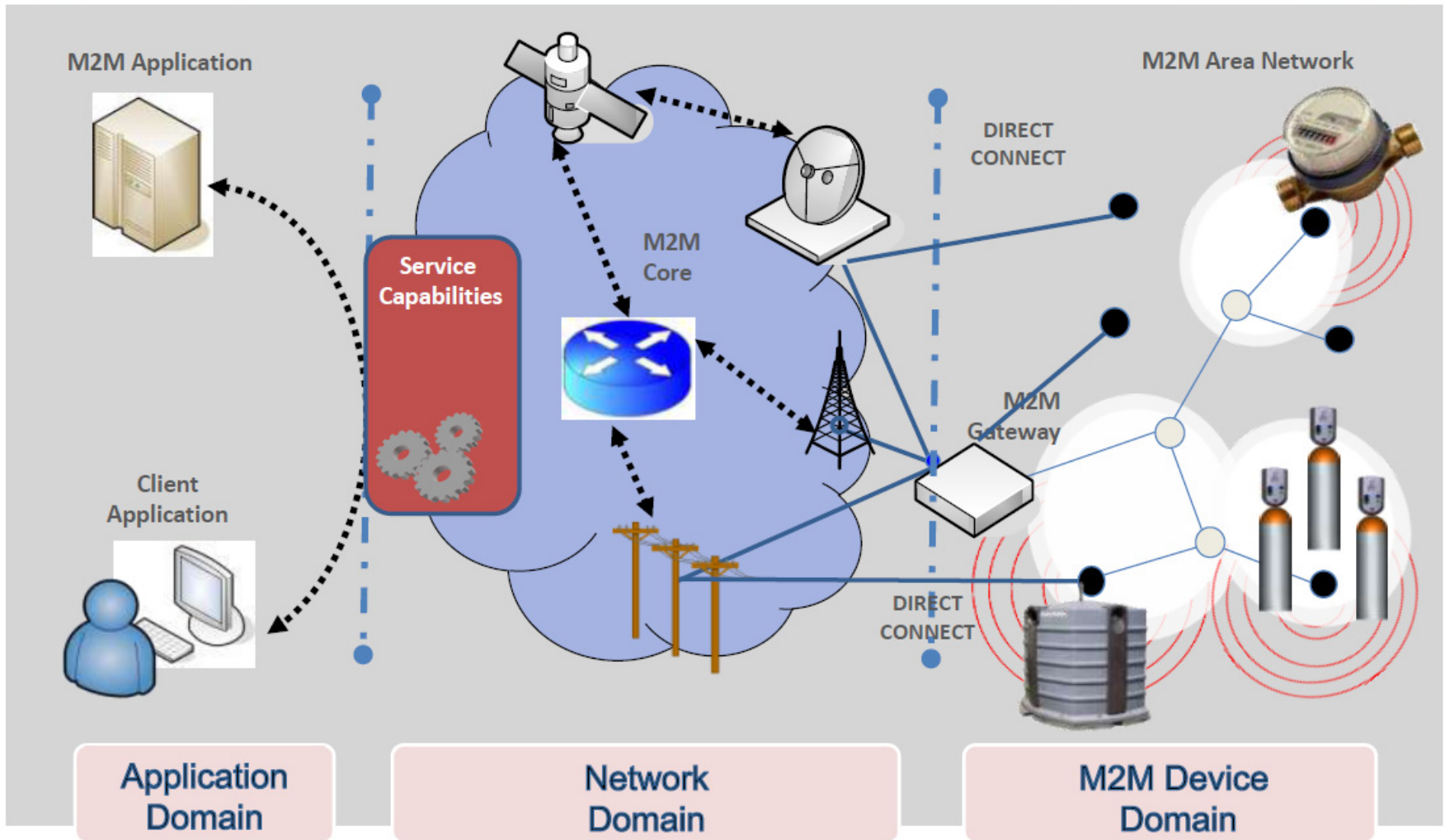
Technical Novelties of Cellular M2M

- Current cellular systems are designed for human-to-human (H2H):
  - we are **not too many users**, in the end
  - we **tolerate delay/jitter**, even for voice connections
  - we like to **download a lot**, mainly high-bandwidth data
  - we don't mind to **recharge** our mobiles on a daily basis (**!!!!**)
  - we raise alert when mobile is **compromised** or stolen

- Accommodation of M2M requires paradigm shift**:**
  - there will be a **lot of M2M nodes**, i.e. by orders of magnitude more than humans
  - more and more applications are **delay-intolerant**, mainly control
  - there will be little traffic per node, and **mainly in the uplink**
  - nodes need to run **autonomously for a long time**
  - automated **security & trust** mechanisms

- … and all this without jeopardizing current cellular services!

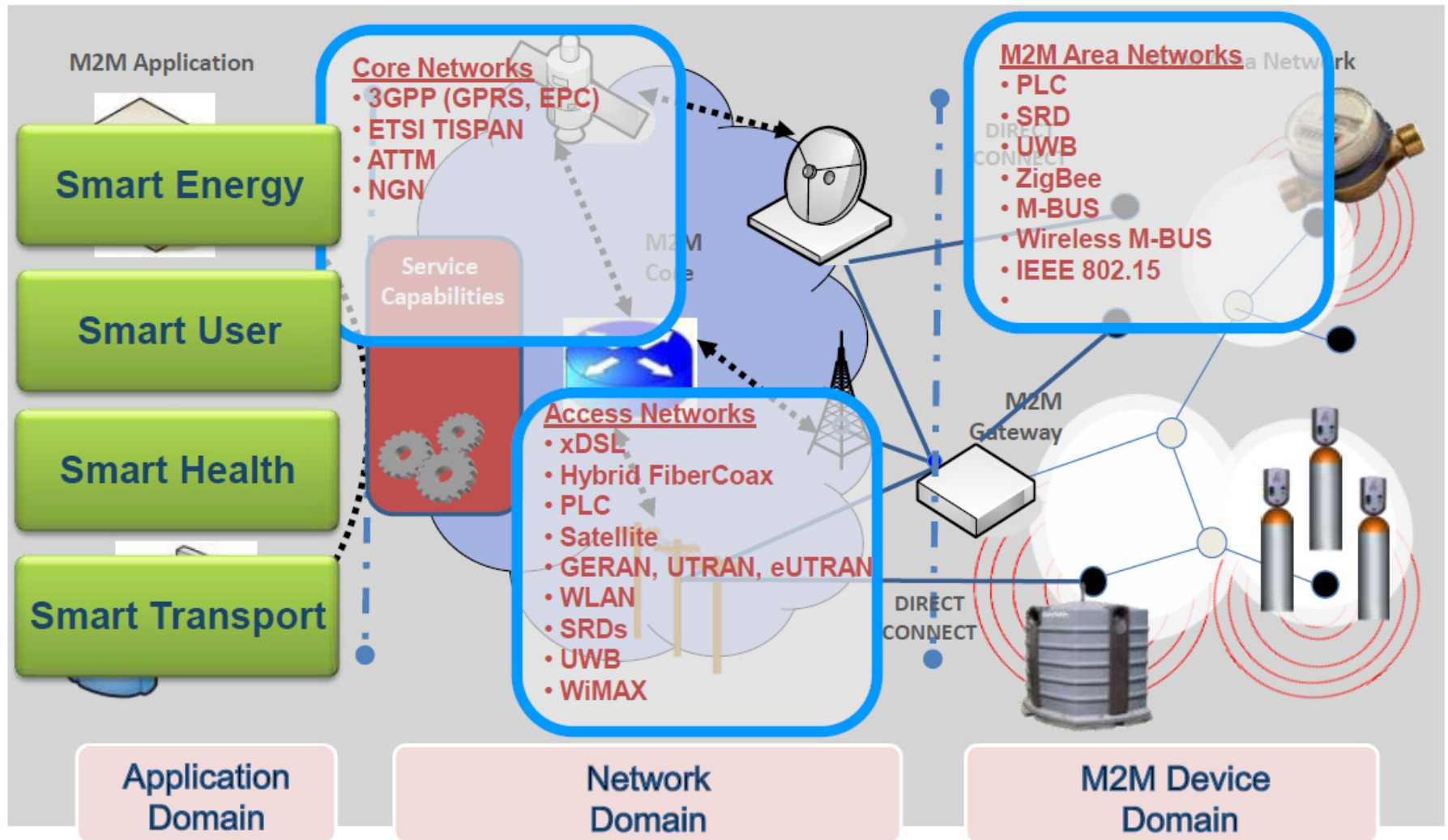# Standards for Cellular M2M

- Industry has become more active in standardizing M2M:
    - Because of the market demand
    - Essential for long term development of technology
    - For interoperability of networks
    - Ability to "roam" M2M services over international frontiers

- Due to potentially heavy use of M2M devices and thus high loads onto networks, interest from:
    - ETSI TC M2M and recently oneM2M Partnership Project
    - 3GPP (GSM, EDGE GPRS, UMTS, HSPA, LTE)
    - IEEE 802.16 (WiMAX)

ETSI: TC M2M Simplified Architecture


© ETSI

ETSI: TC M2M Simplified Architecture

M2M Application

Smart Energy

Smart User

Smart Health

Smart Transport

Core Networks
- 3GPP (GPRS, EPC)
- ETSI TISPAN
- ATTM
- NGN

Service Capabilities

M2M Core

M2M Area Networks
- PLC
- SRD
- UWB
- ZigBee
- M-BUS
- Wireless M-BUS
- IEEE 802.15

DIRECT CONNECT

M2M Gateway

Access Networks
- xDSL
- Hybrid FiberCoax
- PLC
- Satellite
- GERAN, UTRAN, eUTRAN
- WLAN
- SRDs
- UWB
- WiMAX

DIRECT CONNECT

Application Domain

Network Domain

M2M Device Domain

© ETSI

3GPP: Features in M2M

- Standards Document **TS 22.368**: "Service Requirements for Machine-Type Communications (MTC)"
- A ***feature*** is a system optimization possibility
- Not all MTC (M2M) applications have the same characteristics
- Not every optimization is suitable for all applications
- Offered on a per subscription basis:

  - Low Mobility
  - Time Controlled
  - Time Tolerant
  - Small Data Transmissions
  - Mobile originated only
  - Infrequent Mobile Terminated
  - MTC Monitoring

  - Priority Alarm Message (PAM)
  - Secure Connection
  - Location Specific Trigger
  - Infrequent transmission
  - Group Based features
    - Policing
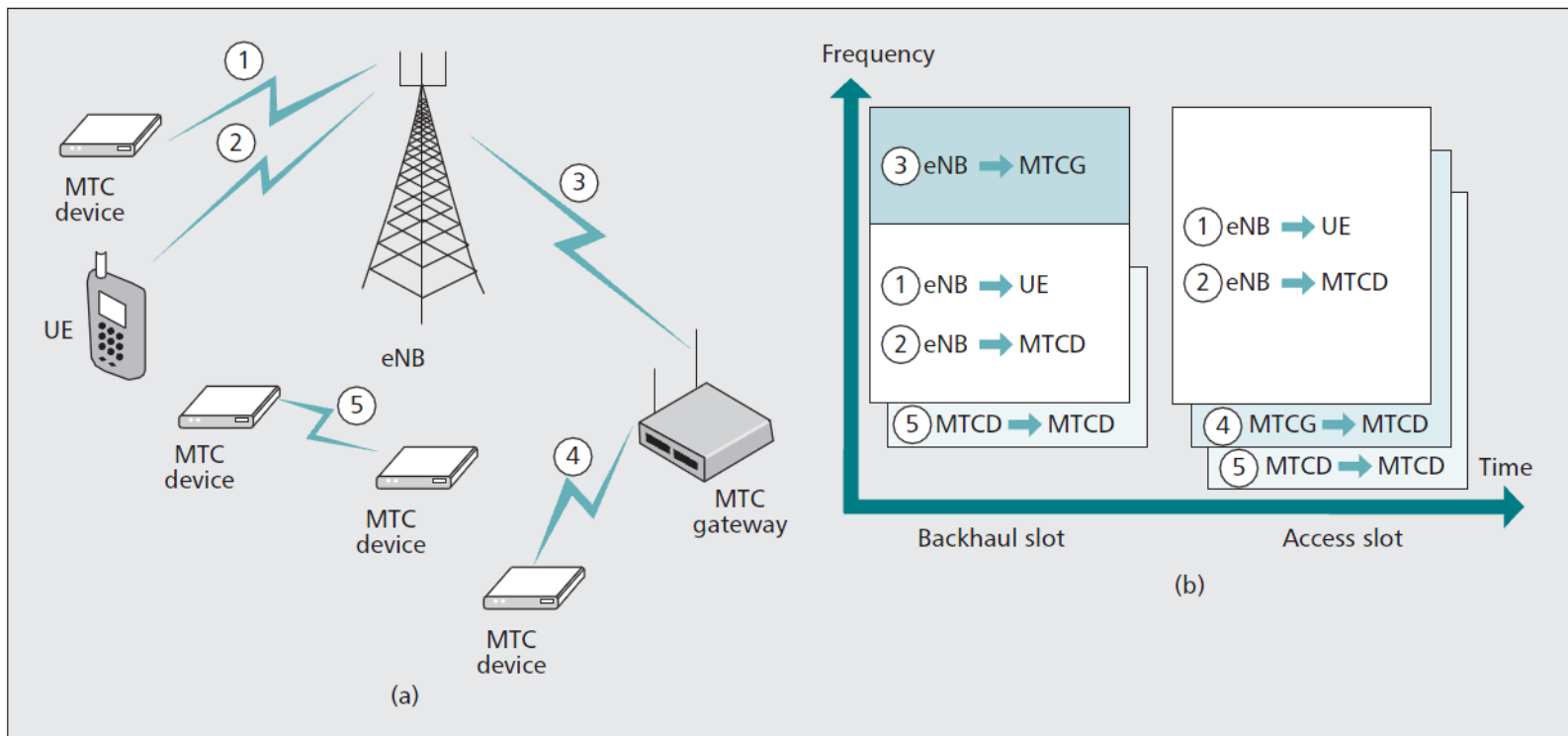   - Addressing

LTE-A RRM with HTC & MTC

■ High-level architecture with 3 different types of controlling MTC:
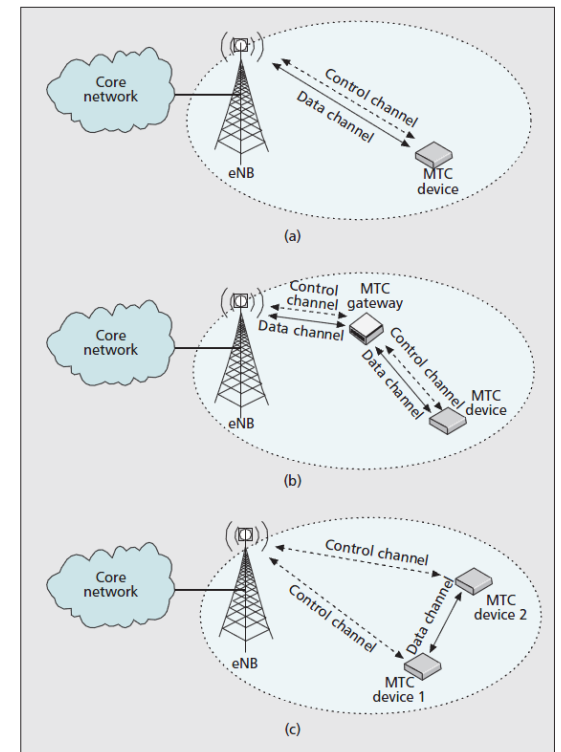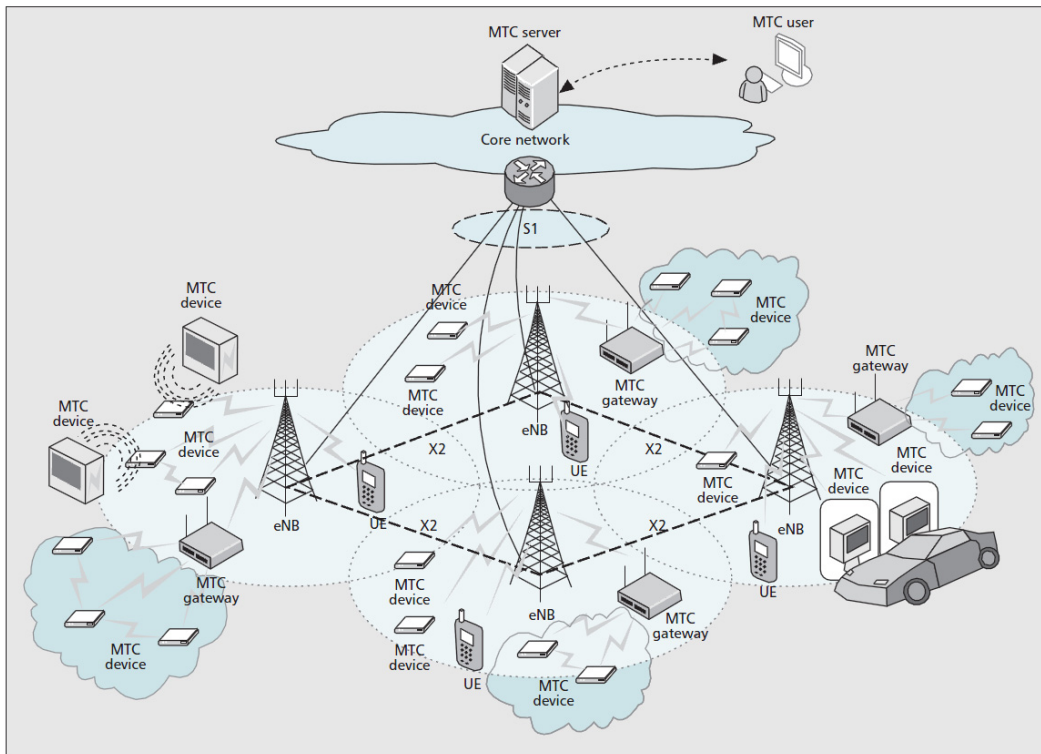
[© K. Zheng, F. Hu, W. Xiangy, Mischa Dohler, W. Wang,
"Radio Resource Allocation in LTE-Advanced Cellular Networks with M2M Communications,
" IEEE Communications Magazine, 2012]

LTE-A RRM with HTC & MTC

- Radio resource partitioning between HTC and MTC:

[© K. Zheng, F. Hu, W. Xiangy, Mischa Dohler, W. Wang,
"Radio Resource Allocation in LTE-Advanced Cellular Networks with M2M Communications,
" IEEE Communications Magazine, 2012]

Impact of MTC onto HTC

■ System assumptions:

- ■ <u>Method 1</u>: HTC is prioritized all the time
- ■ <u>Method 2</u>: MTC is prioritized all the time

| Parameter	Value	
RACH Number	1	
RACH TTI	20ms	
	HTC	MTC
Number	100	100~100,000
Access Frequency Distribution	Poisson	Poisson
Access Frequency [average]	1min	5min/30min
Access Attempt Before Outage	100ms	1000ms

[© Kan Zheng and Mischa Dohler, under development]

Impact of MTC onto HTC

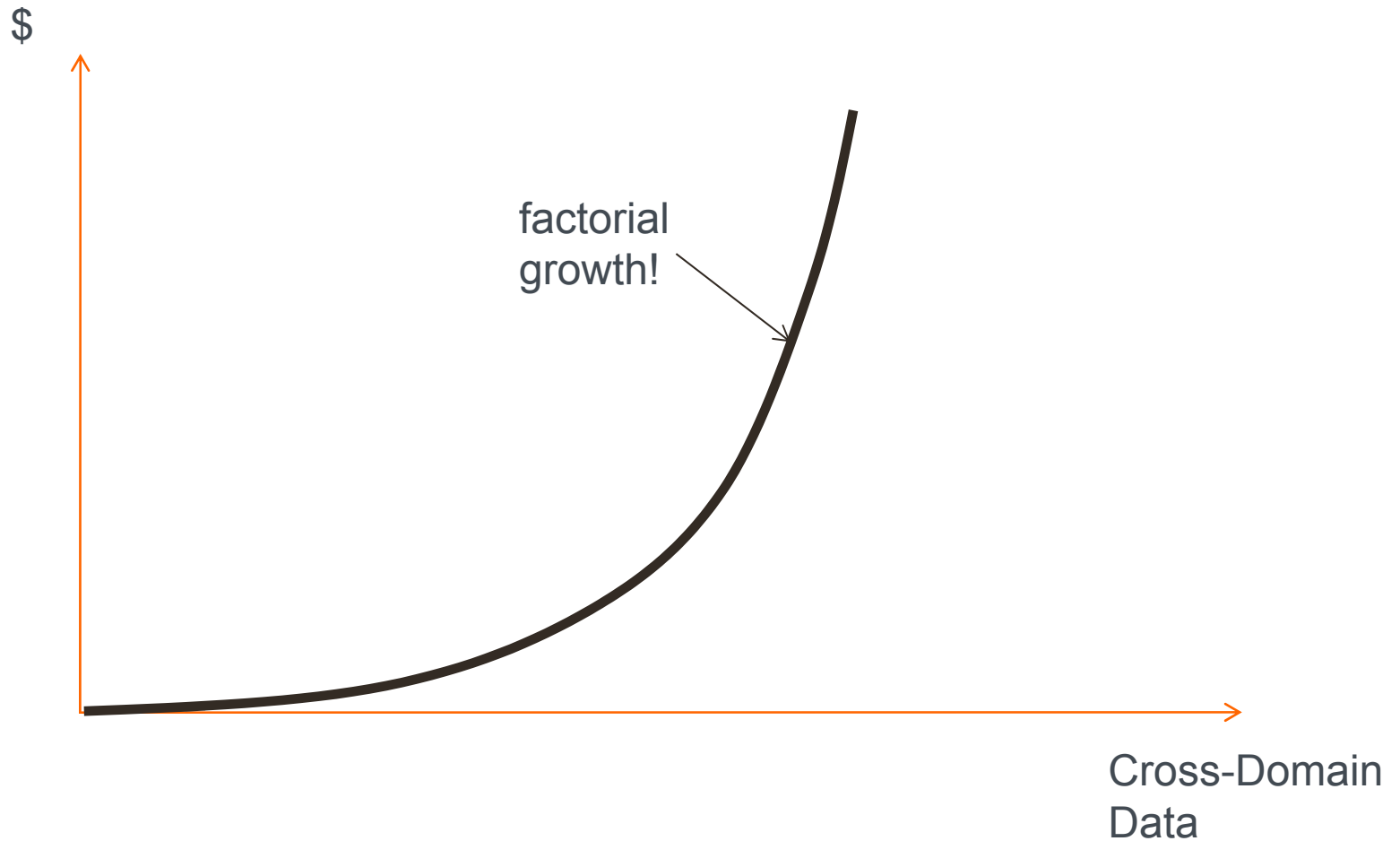- Dropping probabilities, duty cycle and delay for 30min access case:
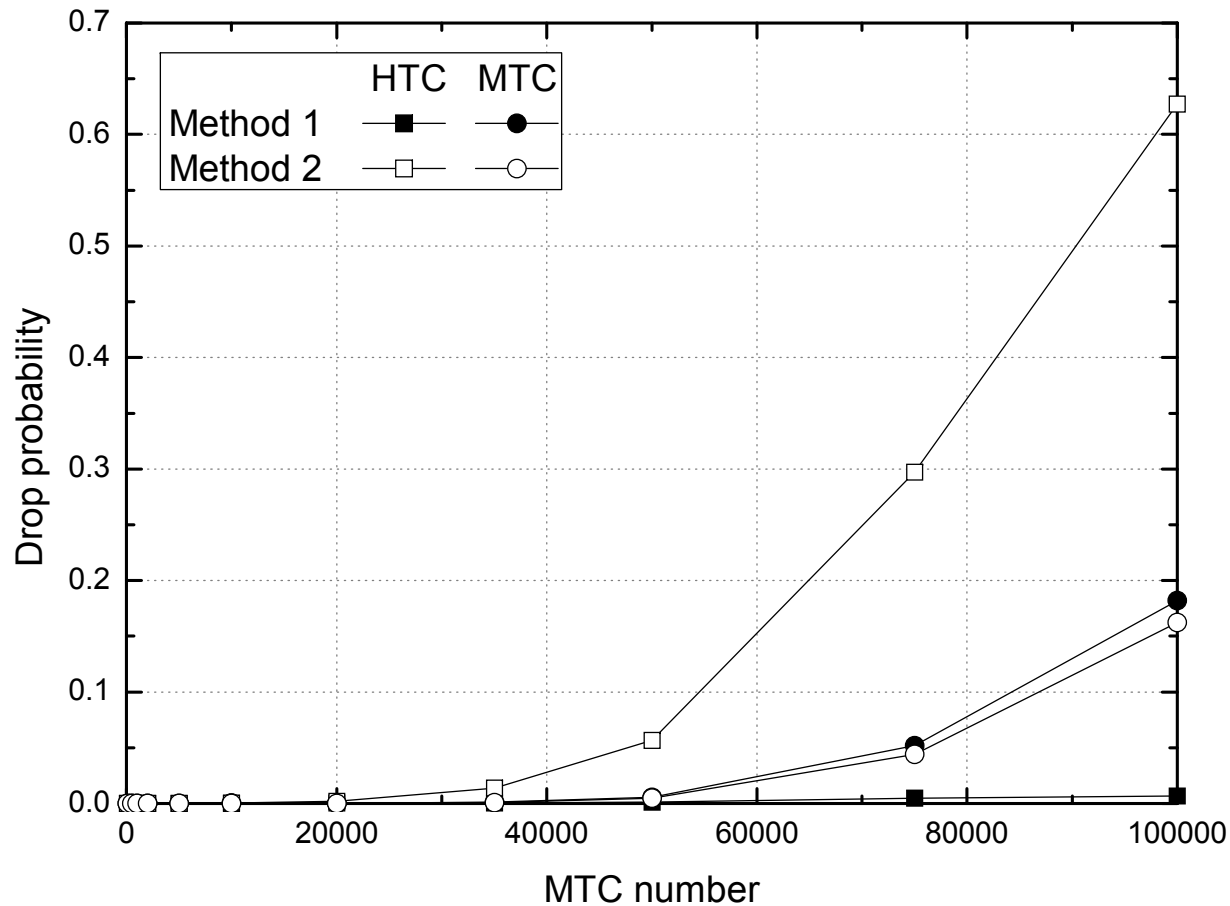
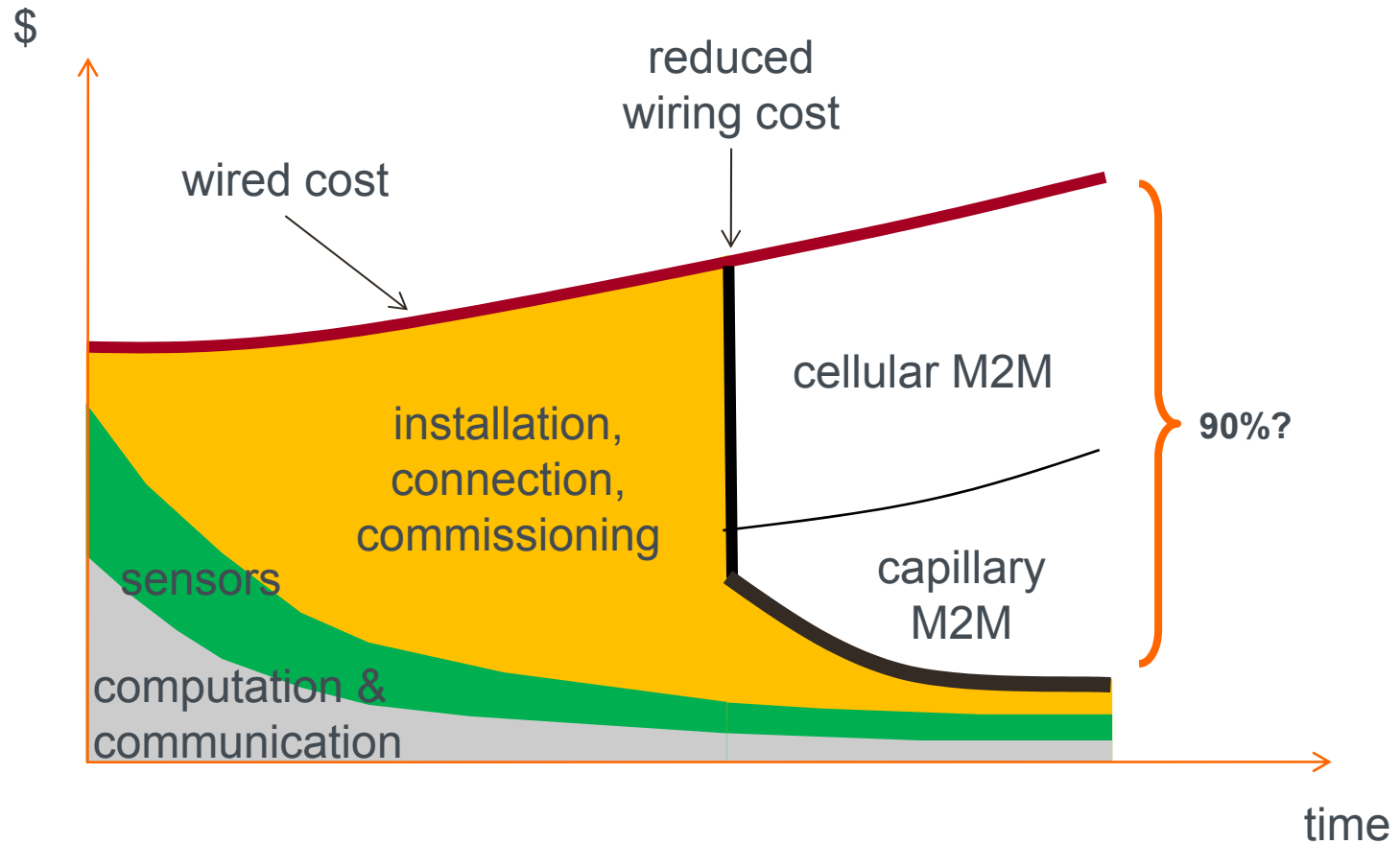# 5

Business & Markets

ROI #1 – Real-Time Instrumentation
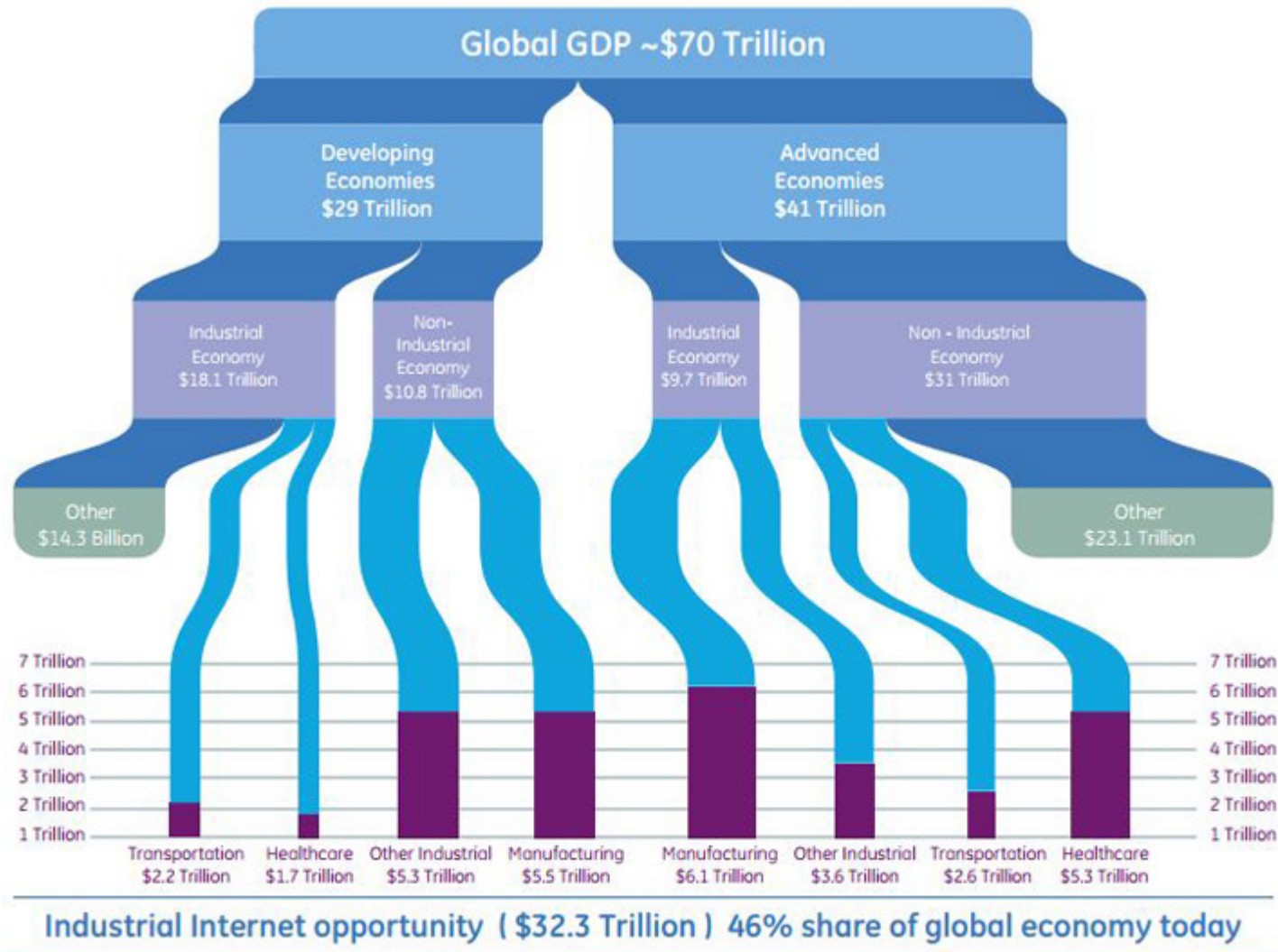
Source: World Bank, 2011 and General Electric

ROI #2 – "Big Data" Value

$
factorial
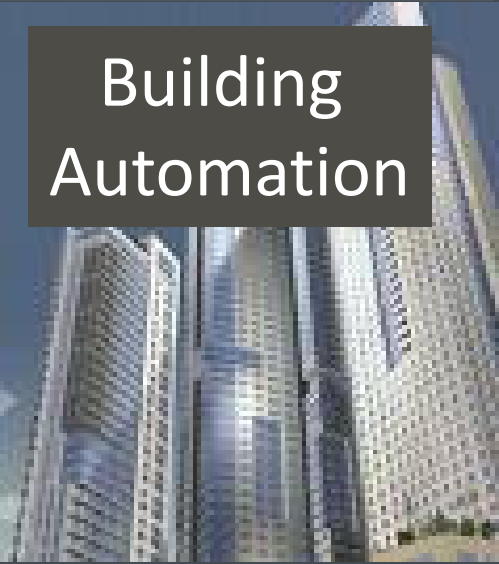growth!

Cross-Domain
Data
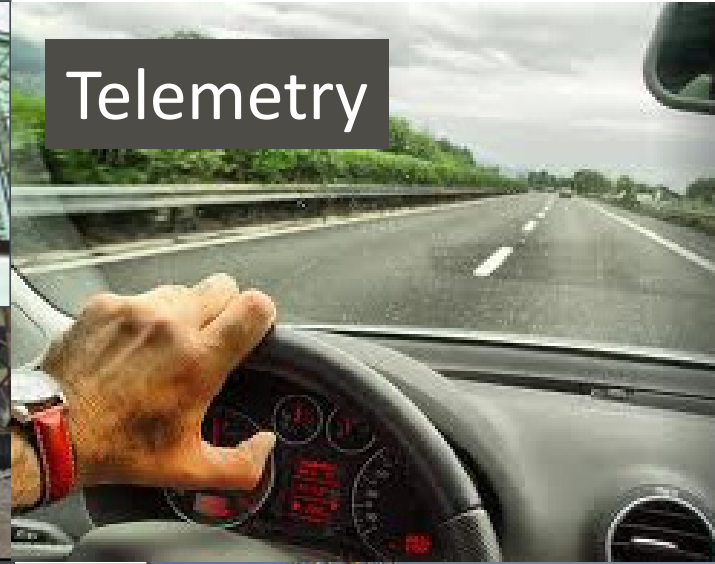
ROI #3 – Savings of Wireless M2M

Popular M2M Markets

Building Automation

Smart City

Telemetry

Smart Grids

Industrial Automation
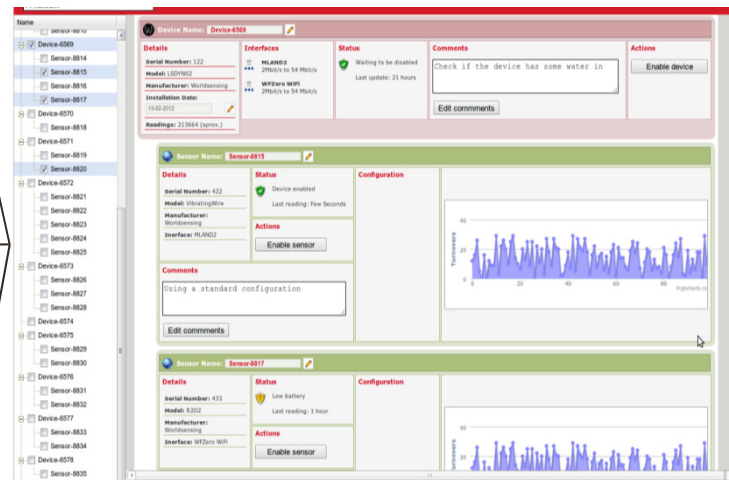
Today's M2M Smart City Reality

Smart Parking

Smart Bins

© Worldsensing

Traffic Flow

Smart City Control Platform

Critical Infrastr.

Travel Time
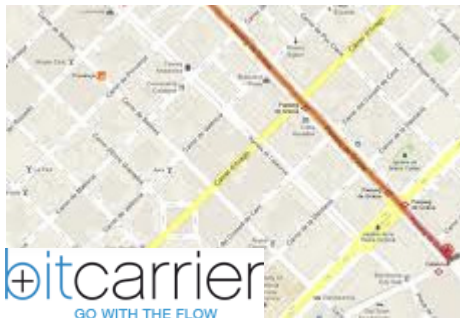
Historic Sites
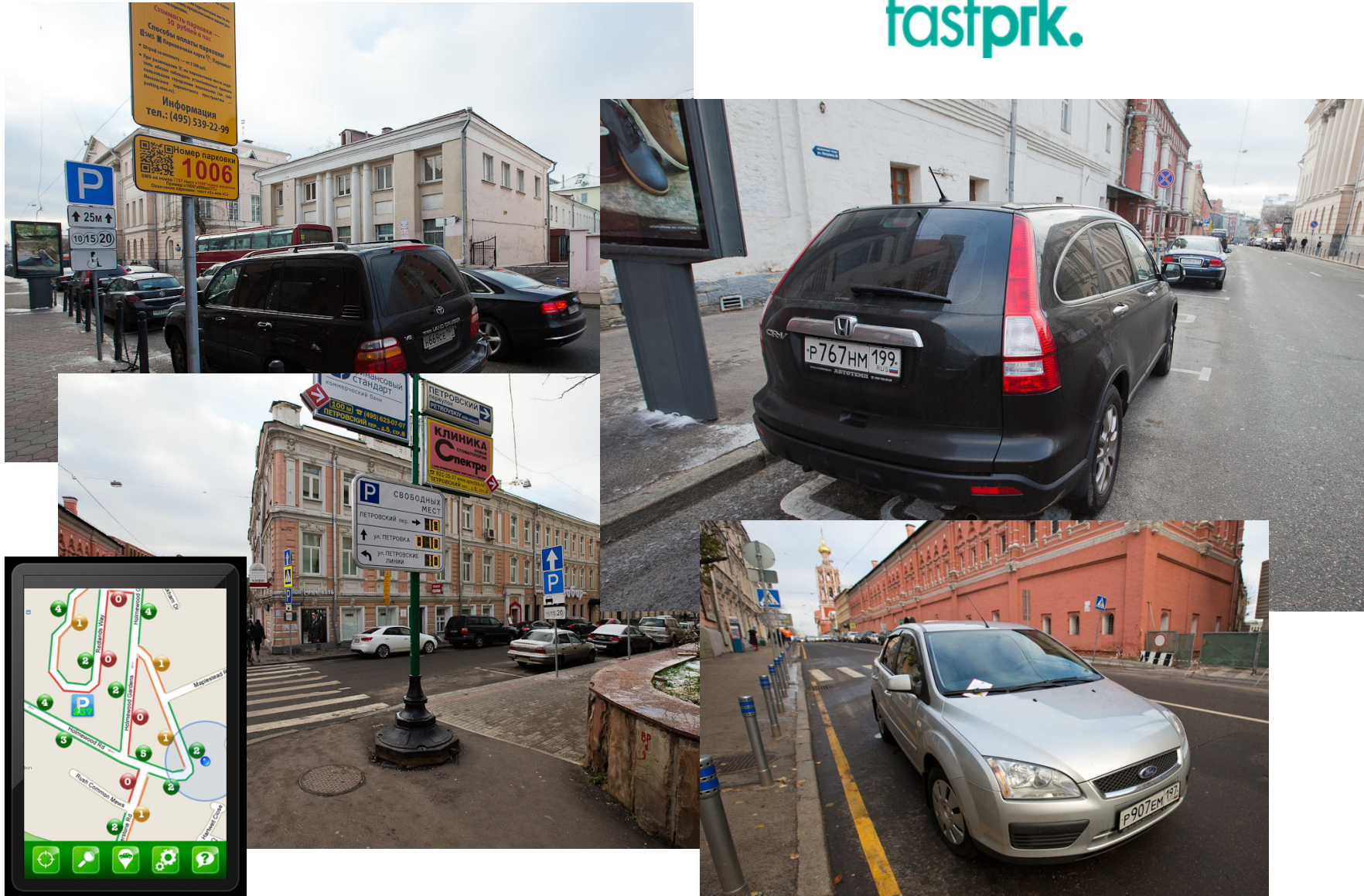

**Proven Technologies
With Solid Deployment
Track-Record Today!**

Example: Moscow Smart Parking

© Worldsensing

Example: Barcelona Harbor

© Worldsensing

- **Problem**: Monitoring beams settlement. 200 biaxial inclinometers. 72 Km of cable. Expensive logistics.

- **Solution**: Loadsensing.com radio nodes and gateway deliver data 24/7 into the Internet and to the company's control centre. Installed in 1 day.

- **Benefits**: monitoring cost greatly reduced; reduction of installation costs. Safety significantly increased: 24/7 connectivity and alert capabilities.

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Concluding Remarks

Machine-to-Machine Predictions

- **Prediction #1:** The capillary embodiment of M2M, Zigbee, will <u>never</u> reach critical mass due to lack of already deployed infrastructure; however, low-power Wifi will scale very quickly.

- **Prediction #2:** With some exceptions, operators will miss out <u>again</u> on the opportunity to become a true service provider, i.e. capitalize on the data content rather than on the data pipe.

- **Prediction #3:** Integrators of integrators & data analytics companies, such as IBM, Oracle, SAP, will capitalize on the true value of M2M; and thus make it an <u>expensive</u> "circle" to be in.

- **Prediction #4:** Uptake of M2M technologies will be much <u>slower</u> than anticipated since marginal business for very large corporations but too-long sales cycles for innovative startups.

THANKS

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