The Future X Network: Building the digital fabric for making cities smarter and better together

Industry Summit 2017, Oulu, 6 Oct 2017

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Ways to save/create time

1) **Change Time**: Use differences in gravity and velocity

2) **Change Lifetime**: Discover "Fountain of Youth" or bioengineered equivalent

3) **Change Usage of Time**: This talk

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Human value: Time

Transcendence Needs
Helping others self-actualize

Self-Actualization Needs
Personal Growth, Self-fulfillment etc.

Aesthetic Needs
Beauty, Balance, Form etc.

Cognitive Needs
Knowledge, Meaning, Self-Awareness etc.

Esteem Needs
Achievement, Status, Responsibility, Reputation etc.

Belonging & Love Needs
Family, Affection, Relationships, Colleagues,Communities etc.

Safety Needs
Protection, Security, Order, Law, Limits, Stability etc.

Biological and Physiological Needs
Basic Life Needs: Air, Food, Drink, Shelter, Warmth, Sex, Sleep etc.

Free Wifi

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Thinking time....

$$\uparrow s^{-1} \rightarrow t \downarrow$$

X 100   X 500   X 1000   X 5000

We have continuously created tools to augment our <u>physical</u> abilities…and save time

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Thinking time....

$$\uparrow D \rightarrow t \downarrow \uparrow$$

X 10 - X 1000 ?

We have created tools to increase discovery to save time (and waste time?)

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Star Trek thinking time....

Communicator   Holodeck   Replicator

$$\downarrow d, E \rightarrow \downarrow t$$

Smartphone   Virtual Reality   3D Printer

Decreasing distance to reduce waste/energy and save time

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Star Trek thinking time….

Transporter

Tricorder

$$\downarrow d, K \uparrow \rightarrow \downarrow t$$

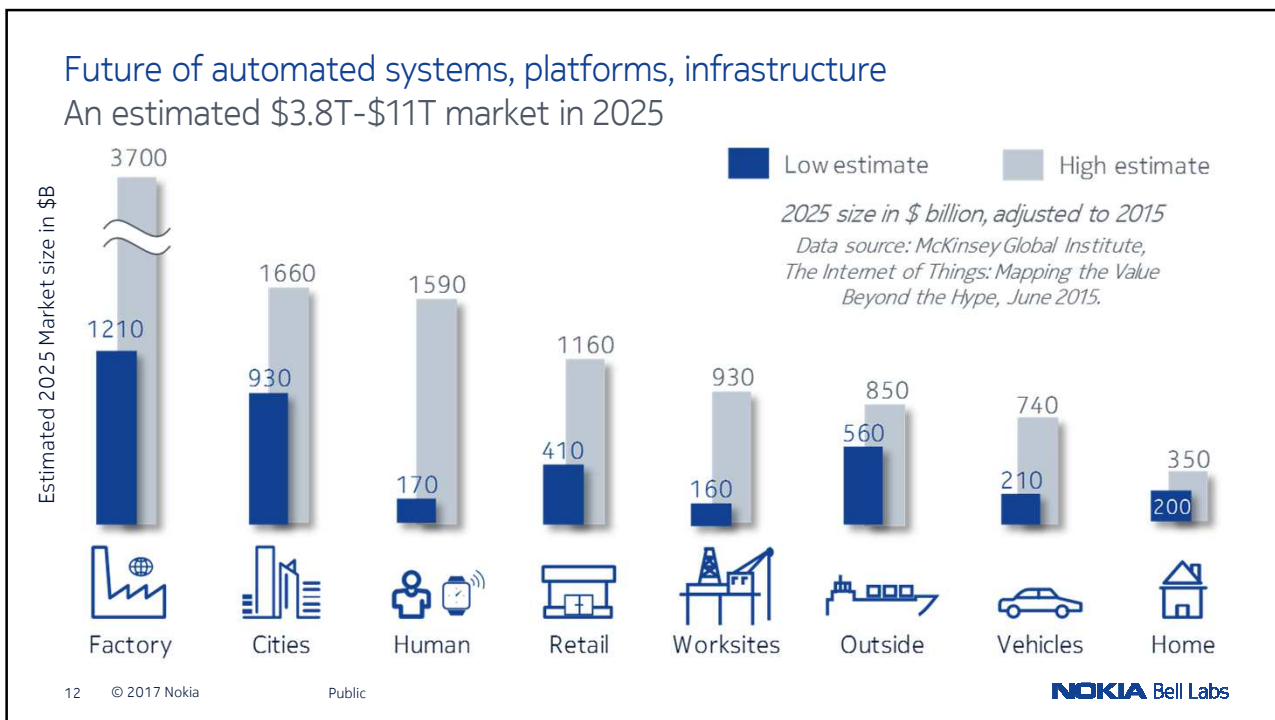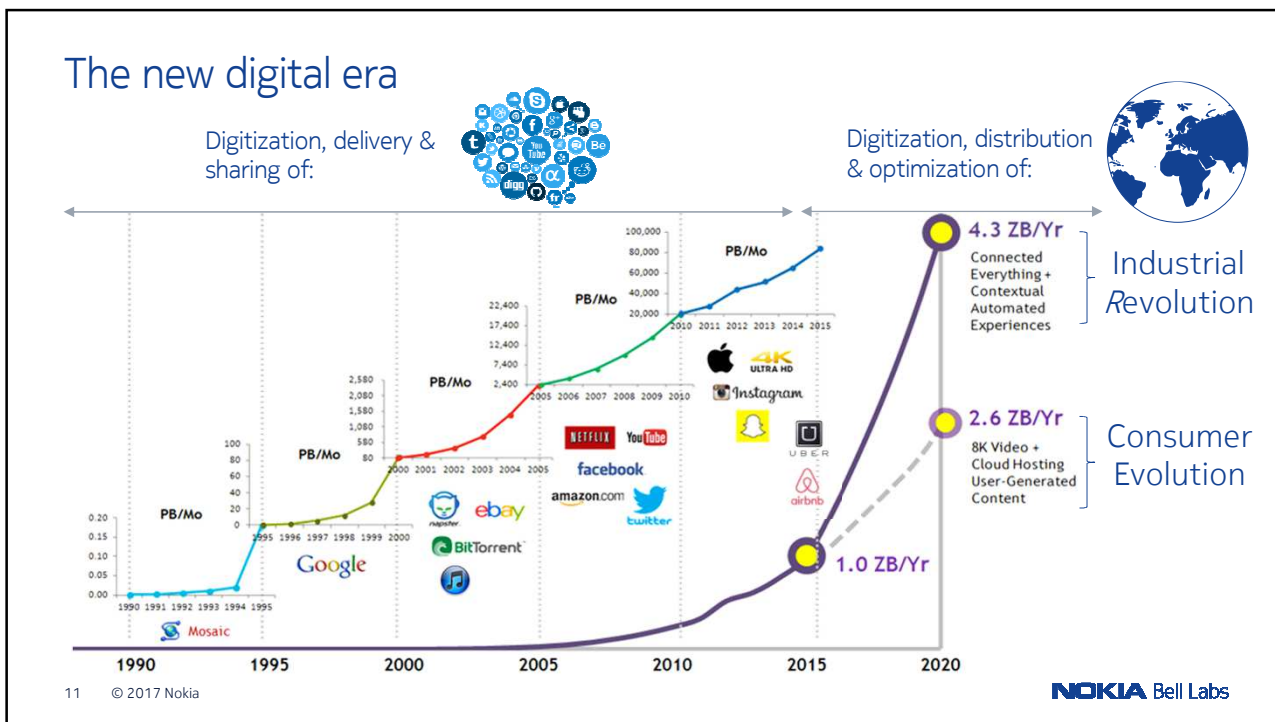**Should decrease distance and increase knowledge to save time…but this remains to be done**

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Thinking time….

Need to interface digital & physical realms…to decrease distance and waste, and create time

5

Technological Revolution

=

Interconnection and interdependence of new systems and technologies

+

The capacity to profoundly transform the economy and eventually society

The revolution

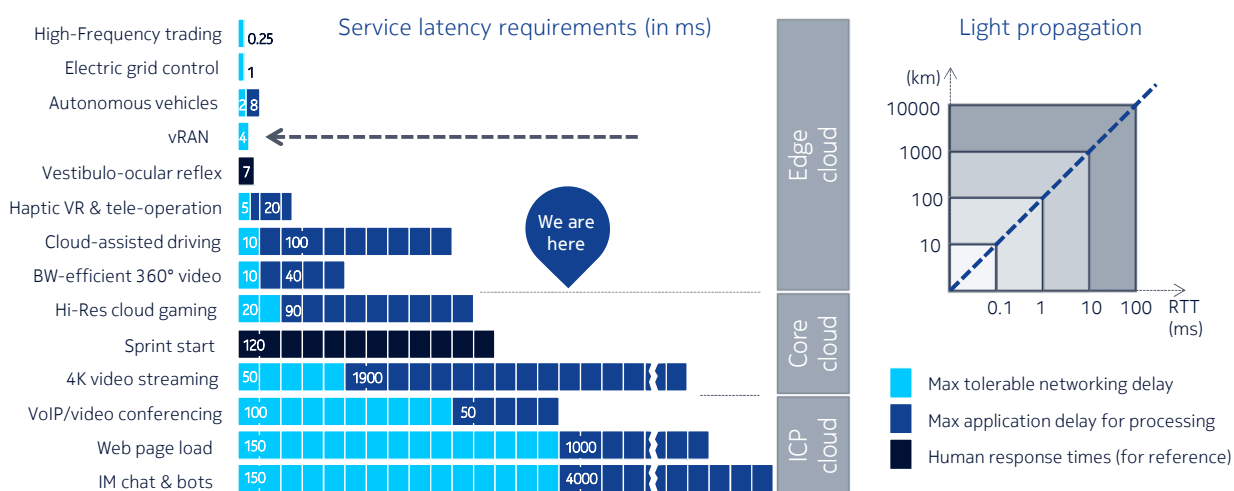| Tech. Revolution	Enabling Technology	Connectivity
Financial (1600 – 1740)	Stocks & Bonds	Banking & Stock Market Infrastructure
1st Industrial (1780 – 1840)	Steam Engine & Iron Production	Rail and Shipping Networks
2nd Industrial (1880 – 1920)	Steel & Chemicals	Extended Transportation Networks Electricity & Telecom Networks
Scientific-Technical (1940 – 1970)	Analog & Digital Signal processing	Digital Communications Network
Information (1985 – 2015)	The Web, Cloud computing & Mobile devices	Internet & Broadband Access
Automation of Everything (2015 –)	**Digital interfaces & Data analysis**	**Future X Network**

We are here

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The new digital era

Digitization, delivery & sharing of:

Digitization, distribution & optimization of:

4.3 ZB/Yr
Connected Everything + Contextual Automated Experiences

Industrial *R*evolution

2.6 ZB/Yr
8K Video + Cloud Hosting User-Generated Content

Consumer Evolution

1.0 ZB/Yr

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Future of automated systems, platforms, infrastructure
An estimated $3.8T-$11T market in 2025

Estimated 2025 Market size in $B

■ Low estimate   ■ High estimate

2025 size in $ billion, adjusted to 2015
Data source: McKinsey Global Institute,
The Internet of Things: Mapping the Value
Beyond the Hype, June 2015.

Category	Low estimate	High estimate
Factory	1210	3700
Cities	930	1660
Human	170	1590
Retail	410	1160
Worksites	160	930
Outside	560	850
Vehicles	210	740
Home	200	350

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Control blocks of industrial robot automation

Requirements:
Safety, Speed, Precision, Accuracy, Reliability, Adaptability

Moore's Law
AI Systems

Digital Models
of the Physical World

Anticipate/
Control

Act at a
distance

Limits

Sense

Actuate

Telepresence
(VR, Haptics)

Human VOR
Response Time

Device
Physics,
Chemistry,
Materials
Speed of
Light

Digital Nervous System

Network Needs:
Bandwidth
Latency
Scale
Security

Hyper-automation

System
Engineering
& Physics

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Latency matters ... reducing time to save time

Service latency requirements (in ms)

Light propagation

High-Frequency trading	0.25
Electric grid control	1
Autonomous vehicles	2 8
vRAN	4
Vestibulo-ocular reflex	7
Haptic VR & tele-operation	5 20
Cloud-assisted driving	10 100
BW-efficient 360° video	10 40
Hi-Res cloud gaming	20 90
Sprint start	120
4K video streaming	50 1900
VoIP/video conferencing	100 50
Web page load	150 1000
IM chat & bots	150 4000

We are here

Edge cloud

Core cloud

ICP cloud

(km)
10000
1000
100
10

0.1   1   10   100   RTT (ms)

■ Max tolerable networking delay
■ Max application delay for processing
■ Human response times (for reference)

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Location Precision

	Speed	Distance Traveled		
		1 ms	**10 ms**	**100 ms**
	1 m/s	1 mm	1 cm	10 cm
	120 km/h	3.4 cm	34 cm	3.4 m
	100 km/h	2.8 cm	28 cm	2.8 m

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Feedback delay and system stability

Increasing Feedback Delay

Feedback Delay

Target Position — Unstable — t

Target Position — Ringing — t

Target Position — Ideal — t

Disturbance

End-to-end latency

5G	4G
~1-3 ms	~50 ms

Reliable, fast orchestration of multi-machine systems

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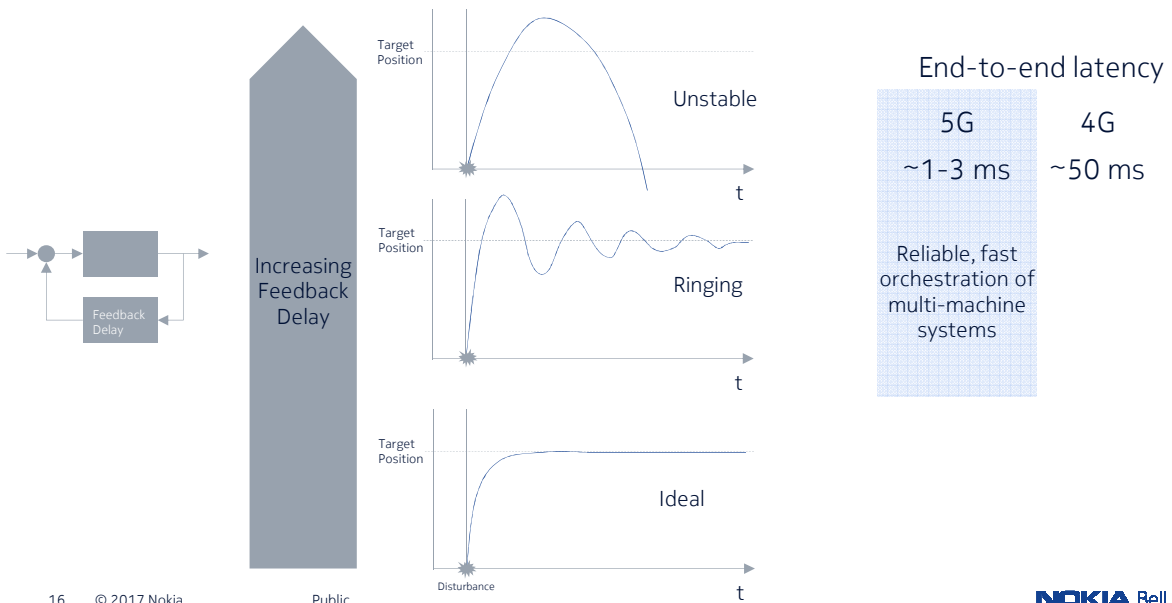
Platoon Collision Avoidance

Networked acceleration, steering and braking control
(inter-vehicular sensing and actuator control)

Latency of 1 ms vs 100 ms @ 100 kmph provides additional safety margin of ~½ car length

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Industrial Automation
High accuracy (μm to mm tolerance)

Laser Welding

Laser Cutting

Industrial robotic control
uses wired communications
(e.g SERCOS)

5G opportunity

• Latencies < 1 ms
• 10^{-8} reliability

Multiple degrees of freedom
in articulation

• Milliradian error can cause
  inaccuracies of several mm

Laser welding system for ships
(Meyerwerft)

• 30 axes for seam weld control
• Speed ~ 10 m/min
• Track radius ~40 mm
• Track accuracy ~ 50 μm

Factories of the future will be enabled by untethered robots providing flexibility, speed and accuracy

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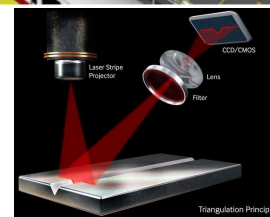
Position Accuracy

Accurate positioning from external sensors
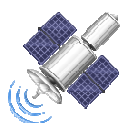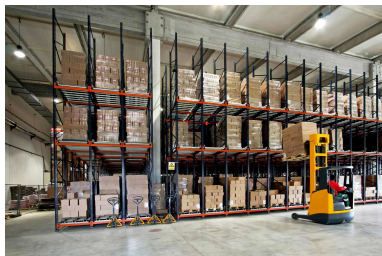
GPS accuracy ~ few meters

Limited to outdoor scenarios

Limited by large obstacles
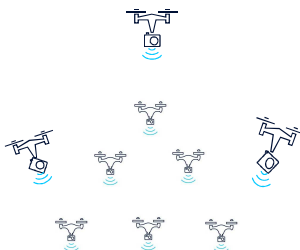
Future networks will enable applications demanding accuracies from few meters down to millimeters

Accurate positioning (observability), controllability and reachability are key in industrial automation/control, transportation, supply chain logistics

Putting 5G's millisecond delays to work

Industrial Robotics

Cooperative Collision Avoidance

3D Printing - Construction

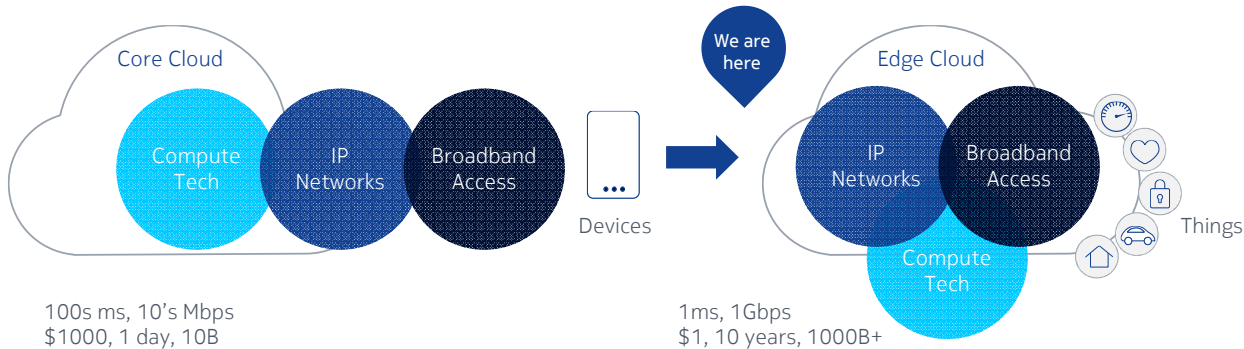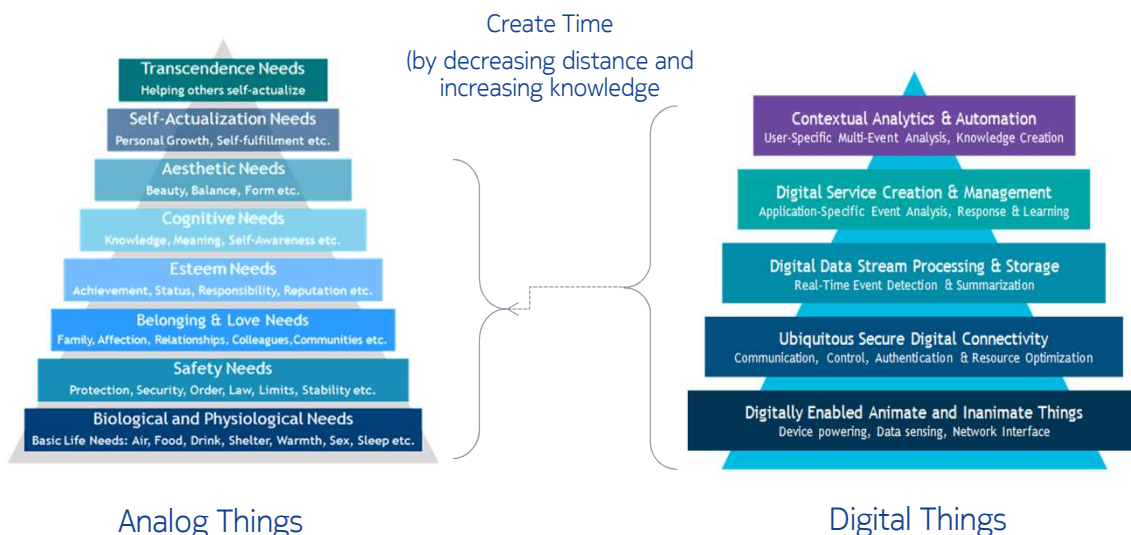Cooperative Robot Control

Cooperative Drone Control

Teleoperation

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10

The New Network: a 100 year - 100x shift

From consumer driven, centralized network

To enterprise driven, distributed network

Core Cloud

Compute Tech

IP Networks

Broadband Access

Devices

We are here

Edge Cloud

IP Networks

Broadband Access

Compute Tech

Things

100s ms, 10's Mbps
$1000, 1 day, 10B

1ms, 1Gbps
$1, 10 years, 1000B+

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The Future of All Things and the Creation of Time

Create Time
(by decreasing distance and increasing knowledge

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Contextual Analytics & Automation
User-Specific Multi-Event Analysis, Knowledge Creation

Digital Service Creation & Management
Application-Specific Event Analysis, Response & Learning

Digital Data Stream Processing & Storage
Real-Time Event Detection & Summarization

Ubiquitous Secure Digital Connectivity
Communication, Control, Authentication & Resource Optimization

Digitally Enabled Animate and Inanimate Things
Device powering, Data sensing, Network Interface

Analog Things

Digital Things

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The Future X Network and the Next Industrial Revolution

Building the digital fabric for the automation of everything and the creation of time

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The Future X Network: The 4 Key Business Value Dimensions