The Convergence of 5G, AI and IoT

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THE CONVERGENCE OF 5G, AI AND IOT

GOALS FOR THIS SESSION

- Gain insight on 5G, AI & IoT, their potential and state of development
- Understand the new context of cross-industry ICT-enabled digitalization
- Review a few digitalization use cases leveraging the combination of 5G, AI and IoT
THE CONVERGENCE OF 5G, AI AND IOT

1. Introduction
2. IoT, AI, 5G: The Technology Ingredients
3. IoT+AI+5G: The new Innovation Factory
4. Challenges (and Opportunities) Ahead
5. Key Takeaways
THE 4TH INDUSTRIAL REVOLUTION

1st Industrial Revolution
Steam-based machines

2nd Industrial Revolution
Energy-based mass production

3rd Industrial Revolution
Computer and Internet-based knowledge

4th Industrial Revolution
Intelligence-based business models

Sources: WEF
PACE OF CHANGE

15 yr
50 b connected devices

25 yr
5 b connected people

100 yr
1 b connected places

Source: Ericsson
DIGITALIZATION DRIVERS 2015-2025

- Real-time Big Data
- AI
- Super-connectivity
- Cloud
THE CONVERGENCE OF 5G, AI AND IOT

1. Introduction
05’

2. IoT, AI, 5G: The Technology Ingredients
15’

3. IoT+AI+5G: The new Innovation Factory
20’

4. Challenges (and Opportunities) Ahead
05’

5. Key Takeaways
05’
SELFIES ARE 100+ YEARS OLD!

Source: Googling
Kevin Ashton coined the term 'Internet of Things' (IoT) in 1999 at Procter & Gamble. 

... everyday objects - such as a refrigerator with embedded sensors or chips could connect to the Internet, enabling autonomous communication with each other and the environment.

The term Artificial Intelligence was coined in 1955 by John McCarthy, a math professor at Dartmouth who organized the seminal conference on the topic. In 1957 Herbert Simon predicted that computers would beat humans at chess within 10 years.

Sources: The Economist, hbr.org/cover-story/2017/07/the-business-of-artificial-intelligence
CONNECTING “THINGS” IN 2001

Sources: Ericsson
IoT SIXTEEN YEARS LATER

Smarter wants to smarten up your dumb kitchen

A trio of new smart devices aims to bring more intelligence to the way you manage your groceries

**Mat:** tells users when a product is almost empty

**Fridge Cam:** allows to see the contents of your refrigerator from anywhere

**Microphone:** detects beeps and alarms from other appliances

Sources: Smarter, Cnet

The Convergence of key ICT Trends for Digitalization | 2018 | Page 11
IoT is relevant not only as a technology that brings efficiencies and value within industry verticals, but a way of **tying** industries, people, and parts of society together to **create substantial value**.
# Cellular for Massive IoT

Meeting diversity of use case requirements

<table>
<thead>
<tr>
<th>Technology</th>
<th>Bandwidth</th>
<th>Coverage</th>
<th>Battery Life</th>
<th>Throughput (peak)</th>
<th>Security</th>
<th>Mobility</th>
<th>Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat-M1</td>
<td>1.4MHz</td>
<td>160dB (+15dB)</td>
<td>10+ Year</td>
<td>0.8/1 Mbps full duplex</td>
<td>Connected &amp; idle mode mobility</td>
<td>SW</td>
<td></td>
</tr>
<tr>
<td>NB-IoT</td>
<td>200kHz</td>
<td>164dB (+20dB)</td>
<td>10+ Year</td>
<td>227/250kbps multi-tone UL</td>
<td>Idle mode mobility</td>
<td>SW</td>
<td></td>
</tr>
<tr>
<td>EC-GSM-IoT</td>
<td>600kHz</td>
<td>164dB (+20dB)</td>
<td>10+ Year</td>
<td>473/473 kbps</td>
<td>Idle mode mobility</td>
<td>SW</td>
<td></td>
</tr>
</tbody>
</table>
‘AI WINTER’

Speech to Text Transcription error rate (%)

Sources: ARK
Puppy or Muffin?

Machines have made real strides in distinguishing among similar-looking categories of images.

Sources: hbr.org/cover-story/2017/07/the-business-of-artificial-intelligence
Artificial intelligence performance has improved exponentially. What's striking is that this substantial improvement has come not over the past 10 years but just since the summer of 2016.

‘Deep learning’ has brought further rapid improvements, producing an accuracy of 96% in 2015, surpassing humans for the first time.

Speech recognition on mobile phones:
- 2011: 25%
- 2012: 15%
- 2013: 11%
- 2014: 6%
- 2015: 4%

Error rates on ImageNet visual challenge, %

Speech recognition on mobile phones:
- 2015: 8.5%
- 2017: 4.9%

ARTIFICIAL INTELLIGENCE
IN FACT PROGRESS IS VERY RECENT

Computer vision accuracy, Microsoft ResNet deep learning algorithm

Source: ARK
5G IN THE DIGITALIZATION CONTEXT

- BIG DATA
- HYPER-CONNECTIVITY
- CLOUD
- AI

https://youtu.be/v56iL9JCw48
WHAT TO EXPECT FROM 5G

1000x Mobile Data Volumes

10x-100x Connected Devices

5x Lower Latency

10x-100x End-user Data Rates

10x Battery Life for Low Power Devices

Source: METIS
### WHAT TO EXPECT FROM 5G

<table>
<thead>
<tr>
<th>Feature</th>
<th>Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Data Rate</td>
<td>1 - 20 Gbps</td>
</tr>
<tr>
<td>User Experienced Data Rate</td>
<td>10 - 100 Mbps</td>
</tr>
<tr>
<td>Spectral Efficiency</td>
<td>×1 - ×3</td>
</tr>
<tr>
<td>Mobility</td>
<td>350 - 500 km/h</td>
</tr>
<tr>
<td>Connection Density</td>
<td>10k - 1m devices / km²</td>
</tr>
<tr>
<td>Network Energy Efficiency</td>
<td>×1 - ×100</td>
</tr>
<tr>
<td>Area Traffic Capacity</td>
<td>0.1 - 10 Mbps / m²</td>
</tr>
<tr>
<td>Reliability</td>
<td>99.999% (of packets)</td>
</tr>
<tr>
<td>Latency</td>
<td>1 - 10 ms</td>
</tr>
<tr>
<td>Battery life</td>
<td>10 years*</td>
</tr>
<tr>
<td>Availability</td>
<td>99.999% (of time)</td>
</tr>
<tr>
<td>Security</td>
<td>Strong subscriber authentication, user privacy and network security</td>
</tr>
</tbody>
</table>

*For low power IoT devices

Source: ITU-R, NGMN, 3GPP
ARE YOU LOST IN TRANSLATION?

WHAT IS 5G?

Very Low Battery Consumption
Ultra-low Latency
Network Slicing
Edge Computing
Location accuracy < 1m
One network supporting Many Logical Networks

E2E Communications delay below 10 ms.

Flexible distribution of Network & Cloud resources

TECHNOLOGY

WHAT’S IN 5G FOR ME?

Optimized On-demand Network & Cloud services
Connected Cars, Drones and Robotics
Innovative VR/AR Industry applications enabled
Pervasive IoT Services
Guaranteed QoS for Mission-critical applications

APPLICATION

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5G is use case driven

Massive MTC
- Low Cost, Low Energy
- Small Data Volumes
- Massive Numbers
- Smart Agriculture
- Logistics
- Fleet Management
- Tracking
- Smart Meter

Critical MTC
- Traffic Safety & Control
- Industrial Application & Control
- Remote Manufacturing
- Remote Training
- Remote Surgery

Enhanced mobile broadband
- Ultra Reliable
- Very Low Latency
- Very High Availability
- VR/AR
- Broadcasting
- 4K/8K UHD
- Non-SIM Devices
- Mobile/Wireless/Fixed
- Venues
- Home
- Enterprise
- Smartphones

5G is use case driven.
ONE NETWORK - MULTIPLE INDUSTRIES

Networks support, learn and adapt to users' and industries' needs
USE CASE EVOLUTION
FROM 4G TO 5G

<table>
<thead>
<tr>
<th>Enhanced Mobile Broadband</th>
<th>Current</th>
<th>On the road to 5G</th>
<th>5G experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Screens everywhere</td>
<td>VR New tools</td>
<td>Immersive experience</td>
</tr>
<tr>
<td>Automotive</td>
<td>On demand information</td>
<td>Real-time information vehicle to vehicle</td>
<td>Autonomous control</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Process automation</td>
<td>Flow management and remote supervision</td>
<td>Cloud robotics and remote control</td>
</tr>
<tr>
<td>Energy &amp; Utilities</td>
<td>Metering and smart grid</td>
<td>Resource management and automation</td>
<td>Machine intelligence and real-time control</td>
</tr>
<tr>
<td>Health Care</td>
<td>Connected doctors and patients</td>
<td>Monitoring and medication e-care</td>
<td>Remote operations</td>
</tr>
</tbody>
</table>

Technologies
- Multi-standard network Cat-M1/NB-IoT
- Cloud optimized network functions
- VNF orchestration
- Gigabit LTE (TDD, FDD, LAA)
- Massive MIMO
- Network Slicing
- Dynamic service orchestration
- Predictive analytics
- NR
- Virtualized RAN
- Federated network slicing
- Distributed Cloud
- Real-time Machine learning/AI
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IoT: ON THE CUSP OF SOMETHING HUGE

$1.9T IoT VALUE-ADD
$11T IoT ECONOMIC IMPACT

$1.3T IoT INVESTMENT
15B IoT CONNECTIONS

Source: IDC, Gartner, Ericsson, McKinsey, AT Kearney
AI: ON THE CUSP OF SOMETHING HUGE

Global GDP will be up to 14% higher in 2030 as a result of the accelerating development and take-up of AI.

The equivalent of an additional $15.7 T
The deployment of 5G in Smart Cities could create up to 3 m jobs and boost GDP by $500 bn; operators are expected to invest ~$275 bn in infrastructure by 2024 in the US.

Source: Accenture, 2017

The global 5G value chain will invest $200 bn annually, will generate ~$3.5 tn in output by 2035, 5G will enable $12.3 tn of global economic output and create 22 m jobs.

Source: IHS, 2017

5G deployment will represent ~€56 bn in 2020 (EU 28). Analysis suggest that 5G investment will have a multiplier impact totaling €141 bn in 2025 in 4 sectors. These effects are likely to create 2.3 m jobs.

Source: EU, 2016

5G: ON THE CUSP OF SOMETHING HUGE

Source: EU, IHS, Accenture
'A CAMBRIAN EXPLOSION'
AI & 5G WILL DISRUPT VIRTUALLY ALL SECTORS

<table>
<thead>
<tr>
<th>Sector</th>
<th>Subsection</th>
<th>Potential AI Consumption Impact</th>
<th>Personalisation</th>
<th>Time To Value</th>
<th>Utility</th>
<th>Data Availability</th>
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<tr>
<td>Healthcare</td>
<td>Preventive Healthcare</td>
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<td>3.4</td>
<td>2.8</td>
<td>3.9</td>
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<td></td>
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<td>3.1</td>
<td>2.4</td>
<td>3.3</td>
<td>4.0</td>
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<td>3.1</td>
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<td>Educational services</td>
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<td>3.0</td>
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<td>3.0</td>
<td>4.0</td>
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<td></td>
<td>Consumer Health</td>
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<td>3.0</td>
<td>3.0</td>
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<td>4.0</td>
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<tr>
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<td>Automotive &amp; Chassis</td>
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<td>3.9</td>
<td>4.2</td>
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<td>Banking and Capital</td>
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<td>3.2</td>
<td>2.9</td>
<td>3.2</td>
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<td>Insurance</td>
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<td>4.0</td>
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<td>3.9</td>
<td>4.2</td>
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<td>Entertainment, Media and Communications</td>
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<td>2.9</td>
<td>3.2</td>
<td>4.0</td>
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<tr>
<td>Retail</td>
<td>Consumer Products</td>
<td>5.3</td>
<td>3.1</td>
<td>3.0</td>
<td>3.3</td>
<td>4.0</td>
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<tr>
<td></td>
<td>Retail</td>
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<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>4.0</td>
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<tr>
<td>Energy</td>
<td>Oil &amp; Gas</td>
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<td>3.5</td>
<td>2.8</td>
<td>3.9</td>
<td>4.2</td>
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<td>Power &amp; Utilities</td>
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<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>4.0</td>
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<tr>
<td>Manufacturing</td>
<td>Aviation Industry</td>
<td>5.5</td>
<td>3.2</td>
<td>2.9</td>
<td>3.2</td>
<td>4.0</td>
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<td></td>
<td>Defence industry</td>
<td>5.1</td>
<td>3.0</td>
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<td>4.0</td>
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<td>Industrial manufacturing</td>
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<td>4.0</td>
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<td>Industrial Resources/Raw Materials</td>
<td>5.1</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Source: Arthur D. Little, PWC, Gill Pratt
THE NEW FACTORY OF INNOVATION

Innovation = F (IoT, AI, 5G)
THE NEW FACTORY OF INNOVATION

Source: Scott Adams / Dilbert
**5TONIC INNOVATION FACTORY**

**EMERGENCIES**
- Save lives of chronic patients, by improving time-to-attention a 50%
- 5G Wearables, Edge Computing, IoT, Device-to-Device Comms, Network Slicing
- Demos scheduled: Sep 2018 and Jan 2019

**TOURISM**
- First Augmented Fair in the World
- Mixed Reality and Augmented Hearing over 5G & Distributed Cloud and Network Slicing
- Demoed at FITUR2018(Jan 2018)

**INDUSTRY 4.0**
- 5G-enabled AGV’s (Automated Guided Vehicles)
- Autonomous Vehicles, Cloud Robotics, 5G & Distributed Cloud
- Demo scheduled for Global Robot Expo 2018 (Apr 2018)

**SPACE & DEFENSE**
- MoU just signed

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CASE 1: ‘FULLY AUTONOMOUS VEHICLES WOULD BE IMPOSSIBLE WITHOUT 5G & AI’

5G wireless will make autonomous cars smarter

Source: Intel, Forbes, VentureBeat

AI critical to the future of autonomous vehicles

Source: Intel, Forbes, VentureBeat
CASE 2: REMOTE ROBOTIC SURGERY

$20.8 BN
Estimated surgical robot market size (2024)

- Improved outcomes
- Patient convenience
- Reduced cost

Source: Ericsson and Arthur D. Little, Kalorama Information
CASE 3: REMOTE CONTROL OF PRODUCTION LINE ROBOTICS

Critical control of production line robotics includes tethered or untethered production line robotics that are controlled, monitored, and can be reconfigured remotely.

<table>
<thead>
<tr>
<th>Technical features</th>
<th>Applications</th>
<th>What role does 5G play?</th>
</tr>
</thead>
<tbody>
<tr>
<td>› Production line robot</td>
<td>› Production on factory floor</td>
<td>› Mobile high performance connectivity for robotics</td>
</tr>
<tr>
<td>› Control center</td>
<td>› Reset and reconfiguring of task</td>
<td>› removing the need for fiber tethering</td>
</tr>
<tr>
<td>› Connection between robot and control center</td>
<td>› Reconfiguration of production layout with mobile robotics</td>
<td>› Quick reactions to discrepancies helps avoid damaging expensive components</td>
</tr>
<tr>
<td>› Specialized tools</td>
<td>› Real-time analysis and steering of robot movements</td>
<td>› Live remote monitoring of video stream from robotics</td>
</tr>
<tr>
<td>› Datacenter/cloud</td>
<td>› Remote control for turning robotics on and off</td>
<td>› Low latency enable remote control applications</td>
</tr>
<tr>
<td>› Haptic feedback controlling device</td>
<td>› Analysis and follow-up</td>
<td></td>
</tr>
<tr>
<td>› Cameras and other sensing devices for feedback to control center</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: 3GPP, Arthur D. Little

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CASE 4: TRUE REAL-TIME SIMULTANEOUS TRANSLATION

APPLICATION

True Real-time Simultaneous Translation Service

5G ROLE

Latency
Security
Connection density
Reliability

REMOTE CLOUD SERVICE

NETWORK

TRADE FAIR CENTER

Internet
5G
Edge Computing Infra
Feria de Madrid
CHALLENGES (AND OPPS) AHEAD

- Industries in Transformation vs New Entrants
- Legacy Systems and Emerging Technologies
- Standard vs Proprietary Solutions
- Established Technology Firms and Start-ups
- Traditional vs New Business Models
- Senior Experienced Staff and Young Talent
- Bilateral vs Multilateral collaborations
If managers aren’t ramping up experiments in the area of machine learning, they aren’t doing their job.

Over the next decade, AI won’t replace managers, but managers who use AI will replace those who don’t.

Erik Brynjolfsson
Intelligent Machines

The Machines Are Getting Ready to Play Doctor

An algorithm that spots heart arrhythmia shows how AI will revolutionize medicine—but patients must trust machines with their lives.

by Will Knight    July 7, 2017
AI KNOWS WHAT YOU’RE GOING TO DO

Challenges

China is using AI to predict who will commit crime next

Sources: Mashable & The Economist

Facial technology

Advances in AI are used to spot signs of sexuality

Machines that read faces are coming
HOW SECURE ARE AI & IoT?

CHALLENGES

DDoS attack disrupted the controlling server for the heating system in two blocks of apartments in Finland (Nov, 2016)

FDA issues new security guidelines so that your pacemaker won’t get hacked (Dec 2016)

Inside the Cunning, Unprecedented Hack of Ukraine’s Power Grid (Mar, 2016)

Sources: media clippings
NEW TERMS: RANSOMWARE OF THINGS

RoT:
Ransomware of Things

- How ransomware is spreading and actual damage can last over even a single device.
- Is it a real threat?
- How can ransomware survive even after an incident?

Sources: ESET
WHO’S RESPONSIBLE IN AI & IoT?
CHALLENGES

- Tesla Autopilot appears to 'predict' accident in front of it
  (Dec 28, 2016)

- An Amazon Echo may be the key to solving a murder case
  (Dec 27, 2016)

Sources: CNBC, TechCrunch
WHERE ARE THE JOBS IN AI & IoT?

CHALLENGES

Amazon's robot army revealed: now has more than **45,000 bots** around the world
*(Jan 4, 2017)*

A Japanese insurance firm replaced 30 workers with IBM's **artificial intelligence** technology
*(Jan 5, 2017)*

Sources: Daily Mail, Business Insider
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THE CONVERGENCE OF 5G, AI AND IOT
KEY TAKE-AWAYS

5G, AI and IoT trigger disruption and innovation in multiple industry sectors

Ecosystem-based Innovation approaches are key to differentiation

Digitalization Challenges = Great Professional Opportunities