INFRASTRUCTURE VENDOR VIEWS
Industry needs, barriers and opportunities

uOSG project final seminar
Aalto University, Espoo
Tuesday 18th of December

Dr. Seppo Yrjola, Nokia Corporate Strategy & Development

100+ years of interference avoidance – from macro to micro operators

Fleming’s transmitter for Marconi’s transatlantic transmission

The Halifax Morning Chronicle, 24 October 1907
Megatrends

- Ubiquitous connectivity
- Multi-Cloud
- Deep analytics
- Industrial Internet of Things
- Regulatory
The world’s most valuable resource is no longer oil

Stagnation in productivity growth

US Productivity Growth

4% 3% 2% 1% 0%

ELECTRICITY & EARLY NETWORKS AGE

INFORMATION AND COMMUNICATIONS AGE

Tale of two industries

Investment in ICT

- Physical industries: 30%
- Digital industries: 70%

Share of GDP

- Physical industries: 70%
- Digital industries: 30%

Annual productivity growth (15 year average)

- Physical industries: 0.7%
- Digital industries: 2.7%

Source: The Technology CEO Council


The best versus the rest

Productivity growth since 2001

- 5% most productive service firms
- 5% most productive manufacturers
- All other manufacturers
- All other service firms

Source: OECD, Wall Street Journal, July 2018
ICT & OT come together 'IOCT'

<table>
<thead>
<tr>
<th>User case</th>
<th>Availability</th>
<th>Cycle time (ms)</th>
<th>Payload size (bytes)</th>
<th># of devices</th>
<th>Service area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion control</td>
<td>&lt;6 x 9's</td>
<td>&gt;2</td>
<td>20</td>
<td>&gt;100</td>
<td>&gt;100 m</td>
</tr>
<tr>
<td>Machine tool</td>
<td>&lt;6 x 9's</td>
<td>&lt;0.5</td>
<td>50</td>
<td>&gt;100</td>
<td>&gt;100 m</td>
</tr>
<tr>
<td>Packaging machine</td>
<td>&lt;6 x 9's</td>
<td>&lt;1</td>
<td>40</td>
<td>&gt;100</td>
<td>&gt;100 m</td>
</tr>
<tr>
<td>Mobile robots</td>
<td>&lt;6 x 9's</td>
<td>&lt;1</td>
<td>40-250</td>
<td>~100</td>
<td>&gt;1 km²</td>
</tr>
<tr>
<td>Cooperative motion control</td>
<td>&lt;6 x 9's</td>
<td>10-100</td>
<td>5-150</td>
<td>~100</td>
<td>&gt;1 km²</td>
</tr>
<tr>
<td>Video operated remote control</td>
<td>&lt;6 x 9's</td>
<td>4-8</td>
<td>40-250</td>
<td>~100</td>
<td>&gt;10 m</td>
</tr>
<tr>
<td>Mobile robots</td>
<td>&lt;6 x 9's</td>
<td>&lt;1</td>
<td>40-250</td>
<td>~100</td>
<td>&gt;10 m</td>
</tr>
<tr>
<td>Mobile control panel with safety functions</td>
<td>&lt;6 x 9's</td>
<td>&lt;1</td>
<td>40-250</td>
<td>~100</td>
<td>&gt;10 m</td>
</tr>
<tr>
<td>Process monitoring</td>
<td>&lt;6 x 9's</td>
<td>&gt;150</td>
<td>Variable</td>
<td>&gt;10000</td>
<td>devices per km²</td>
</tr>
</tbody>
</table>


Dependability - Ability to perform as and when required

<table>
<thead>
<tr>
<th>OT</th>
<th>ICT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission-critical</td>
<td>Availability &amp; Reliability</td>
</tr>
<tr>
<td>Specialized</td>
<td>Technologies</td>
</tr>
<tr>
<td>Business process control</td>
<td>Service(s)</td>
</tr>
<tr>
<td>Dependability</td>
<td>Operations</td>
</tr>
<tr>
<td>Slow (decades)</td>
<td>Rate of tech change</td>
</tr>
</tbody>
</table>

Carrier-grade
General-purpose/standardized
Media delivery & information services
General-purpose/centralized
Rapid (months to years)
Evolution to mission-critical applications - Precision & Augmented Intelligence

- Bandwidth: 10Gbps, 100Mbps, 1Mbps, 10kbps
- Latency: 10s, 1s, 100ms, 10ms, 1ms, 100us

- 360 Video
- VR+VRAN+Vehicles
- People & Things
- System Control

Evolution to Internet of Skills
New investors unlock 5G potential

- The Industrial Opportunity
- The Mobile Broadband Opportunity

- Early Adopters
- Industrials
- CSPs
- Disruptors
Modernization of industry drives massive economic impact

<table>
<thead>
<tr>
<th>Industry</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport venues &amp; ports</td>
<td>50,000</td>
</tr>
<tr>
<td>Military bases</td>
<td>10,000</td>
</tr>
<tr>
<td>Warehouses</td>
<td>3,300,000</td>
</tr>
<tr>
<td>Industrial &amp; manufacturing</td>
<td>10,710,000</td>
</tr>
<tr>
<td>Oil &amp; gas</td>
<td>8,000</td>
</tr>
<tr>
<td>Power generation</td>
<td>47,600</td>
</tr>
<tr>
<td>Water utility plants</td>
<td>140,000</td>
</tr>
<tr>
<td>Mining</td>
<td>54,000</td>
</tr>
<tr>
<td>Hospitals &amp; labs</td>
<td>263,000</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>14,582,600</strong></td>
</tr>
</tbody>
</table>

Comparison: Global base stations sites: ~7M
Source: Harbor Research

$3.8T to $11T
Economic value of IoT (by 2025)
Source: McKinsey

up to 11% of global economy (in 2025)
Source: McKinsey

The future architecture – Defined by physical limits of spectrum and distance

20x Spectrum
2x Mid & High Band
2x–5x mMIMO
>10x FTTx

2x–20x Spectrum

Distance (traveled by light, km)

Edge Cloud

RTT (ms)
Different spectrum models for different business models

Factors influencing resource valuation and prices
New value architecture: distributed, deterministic & dynamic

The opportunity is here and now