TouCHES
Tactile CyberpHysical nEtworkS
2016-2019

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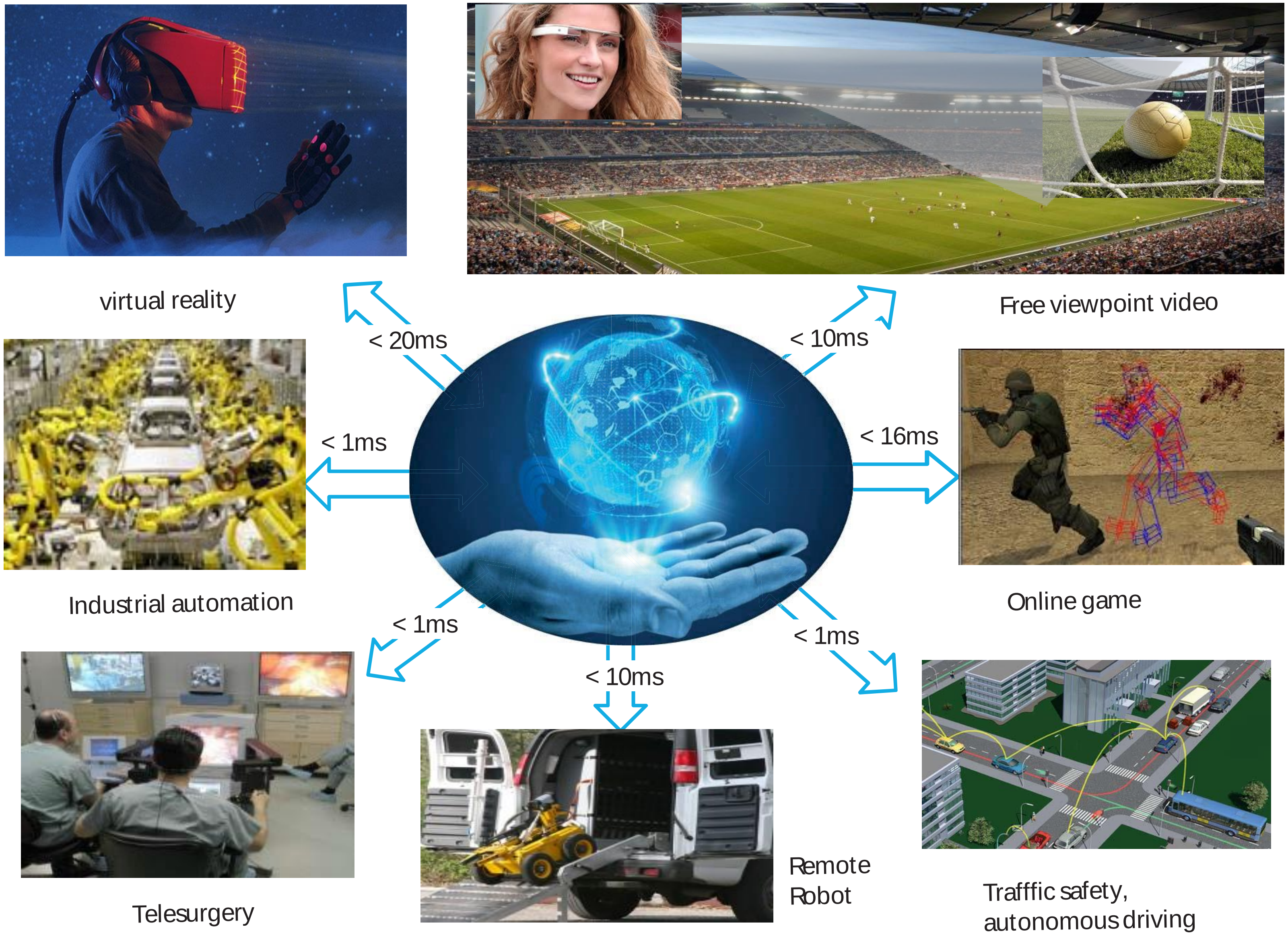
Why low-latency IoT systems



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Some Use Cases

TABLE I
THE REQUIREMENT FOR LOW LATENCY APPLICATIONS

	Latency	Reliability	Other
Assembly line [5], [9]	0.5 ms	99.9999999 %	-
Virtual reality [10]	1 ms	-	-
Automated guided vehicle [5], [9]	few ms	99.99999%	high data rate
Remote control robots [5], [9]	few ms	99.999%	-
Free viewpoint videoing [5]	few ms	-	strong processing capability
Financial market [5]	few ms	high	
Tele-surgery [5], [11]	1-10 ms	98 %	high data rate
Exoskeletons and Prosthetic hands [5], [12], [13]	few ms	high	-
Advanced metering [14]	12-20 ms	-	-
Distributed automation [14]	$<$ 15 ms	-	-
Online games [15]	$<$ 100ms	-	high data rate

The research vision

- Future Internet of Things (IoT) systems will have huge impact only if secure communications with **ultra-low-latency** will materialize

- Currently there is no fundamental design method capable to ensure real-time and secure communications

- We propose to investigate the most prominent design principles for future near-to-zero latency IoT systems

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The Partners

- ACREO
  - Anders Berntsson and Jonas Mårtensson
- KTH – Automatic Control
  - Carlo Fischione and Dimos Dimarogonas
- KTH – Computer Networks Lab
  - Panos Papadimitratos
- KTH – Computer Vision and Active Perception Lab
  - Petter Ögren
- SICS
  - Bengt Ahlgren
- Industrial collaborators
  - ABB
  - Ericsson
  - MIND Music Labs

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The Work Packages

- WP1: **Networking** [CF; co-participants: AB, BA, CF, PP, Ericsson, ABB]
- WP2: **Security** [PP; co-participants: CF, AB, Ericsson, ABB]
- WP3: **Networked Control** [DD; co-participants: CF, PÖ, ABB]
- WP4: **Robotic** [PÖ; co-participants: CF, DD, ABB]
- WP5: **Coordination and Demonstration** [AB; co-participants: ALL]

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WP1: Networking

- **Task 1**: identification of all the components of a high-performance network infrastructure
- **Task 2**: investigation of new distributed routing decision methods capable to minimize the delay by design
- **Task 3**: new dynamic control and management techniques based on optimization theory

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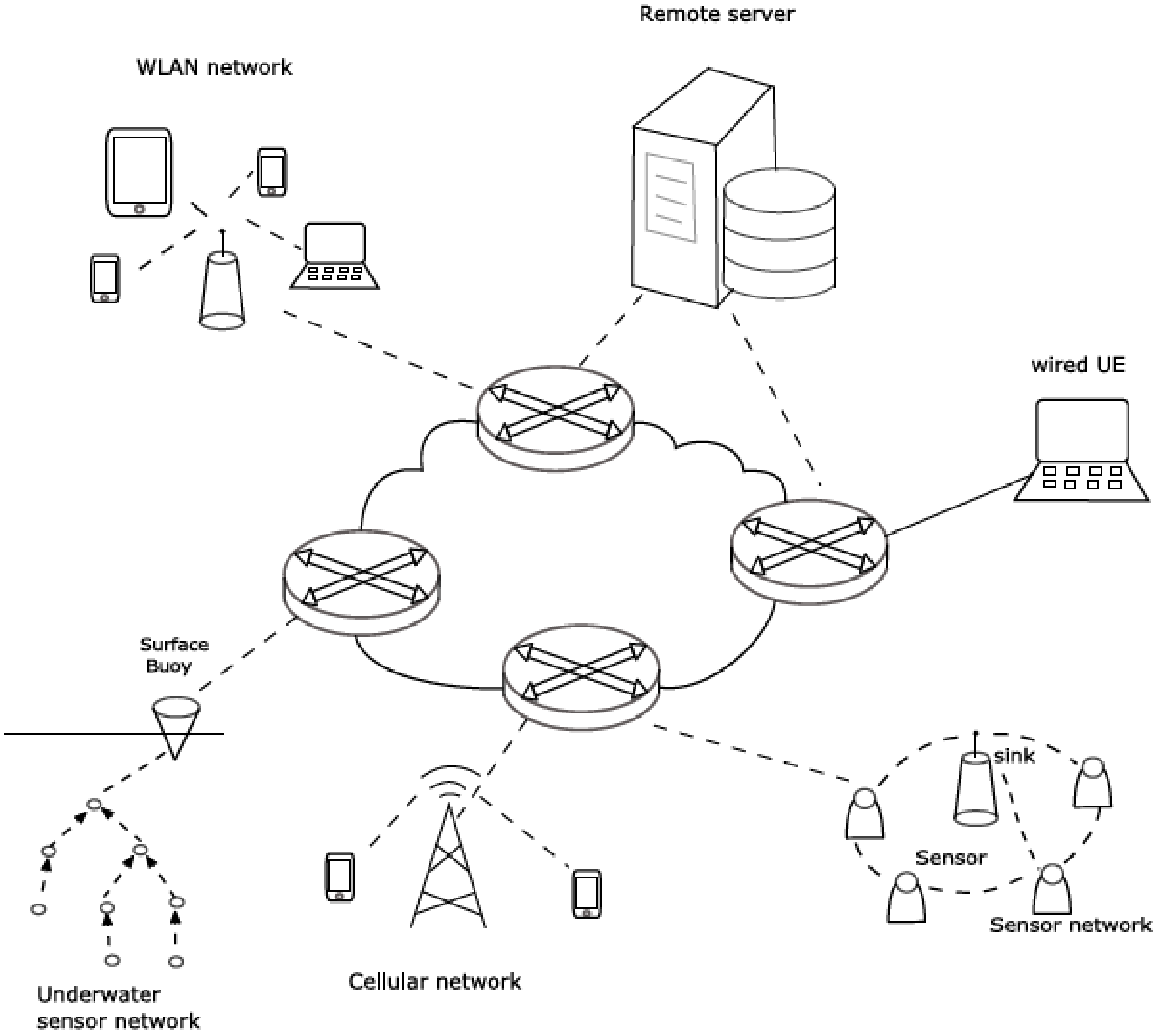

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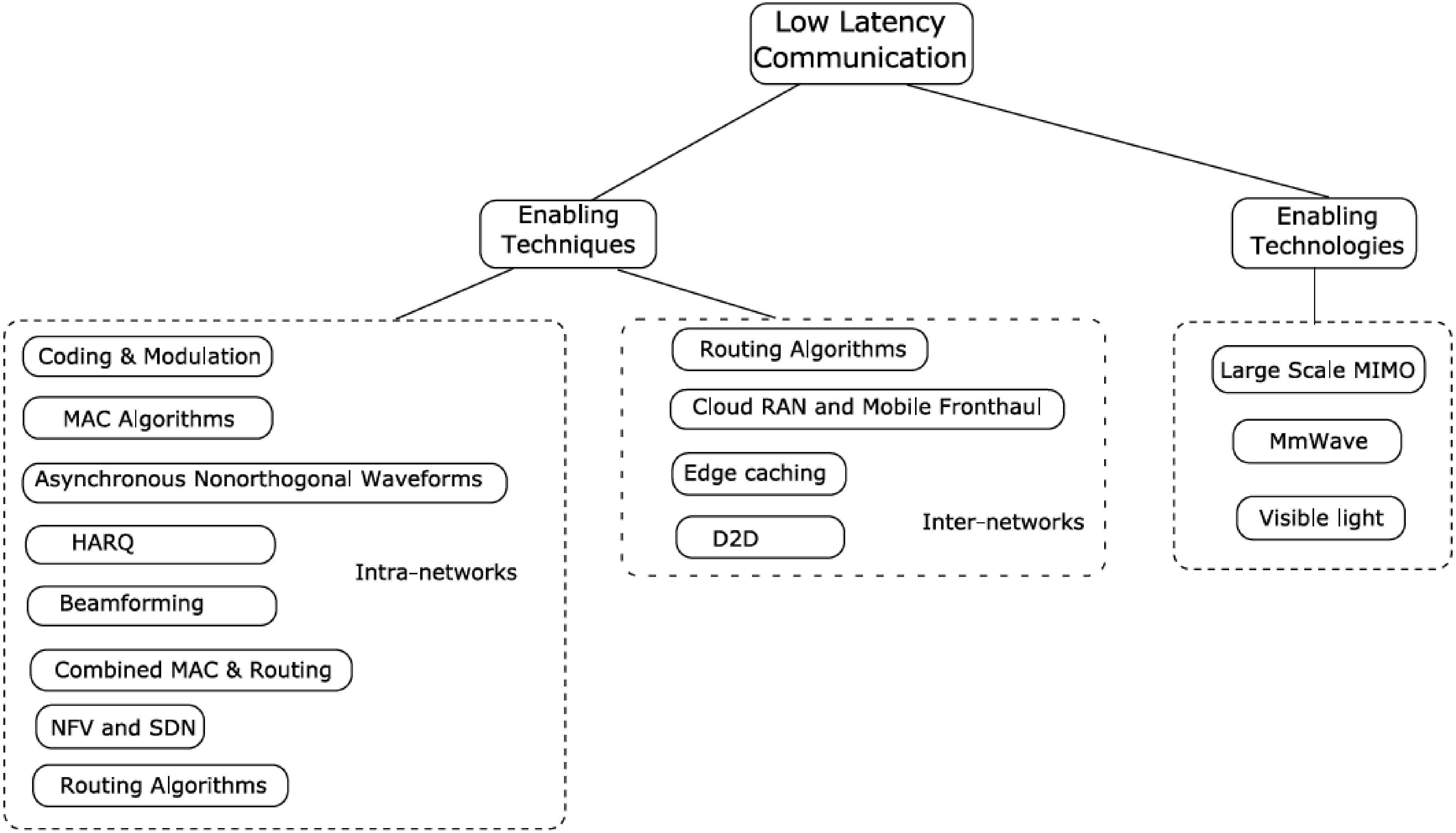
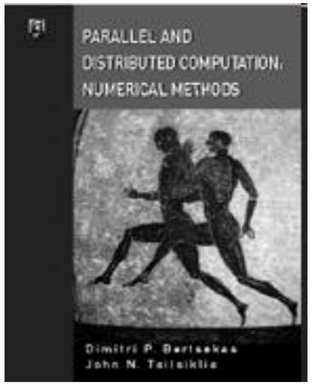


Optimization theory for network operations



- Network optimization today
  - Parallel and distributed computation, fundamental theory for in-network optimization
  - E.g., control-networks co-design, cross layer networking, Medium Access Controls optimization, routing

- Problems:
  - Need of fast solver algorithms of low complexity
  - Fast changing networks, little time to compute solution
  - Security concerns

- Research vision:
  - Distributed optimizations of low communication cost
  - Privacy and security in the optimizations

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WP2: Security

- **Task 1**: Security associations, access control, network and data exchange protection
- **Task 2**: Integrate security and privacy
- **Task 3**: Cater to stringent timing constraints
  - Illustrations based on existing results that can serve as a substrate

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Distributed ETC within Touches

- **Task 1**: ETC based on levels of state quantization and communication with very small delay

- **Task 2**: Fundamental tradeoff in delays and minimum information available that will enhance the requirements for the tactile infrastructure

- **Task 3**: Distributed scheduling (temporal logic specifications) aspects arising from the above described tradeoff

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WP4 Proposed Research

- **Goal capability:**
  - Low latency tele-operation
  - with immersive real-time decision support
  - provided by cloud computing

- **Areas to Explore**
  - Model Predictive Control (MPC) using real time sensor data and cloud computing
  - Monte Carlo Tree Search (MCTS) in the cloud to adapt to actions of other nearby agents

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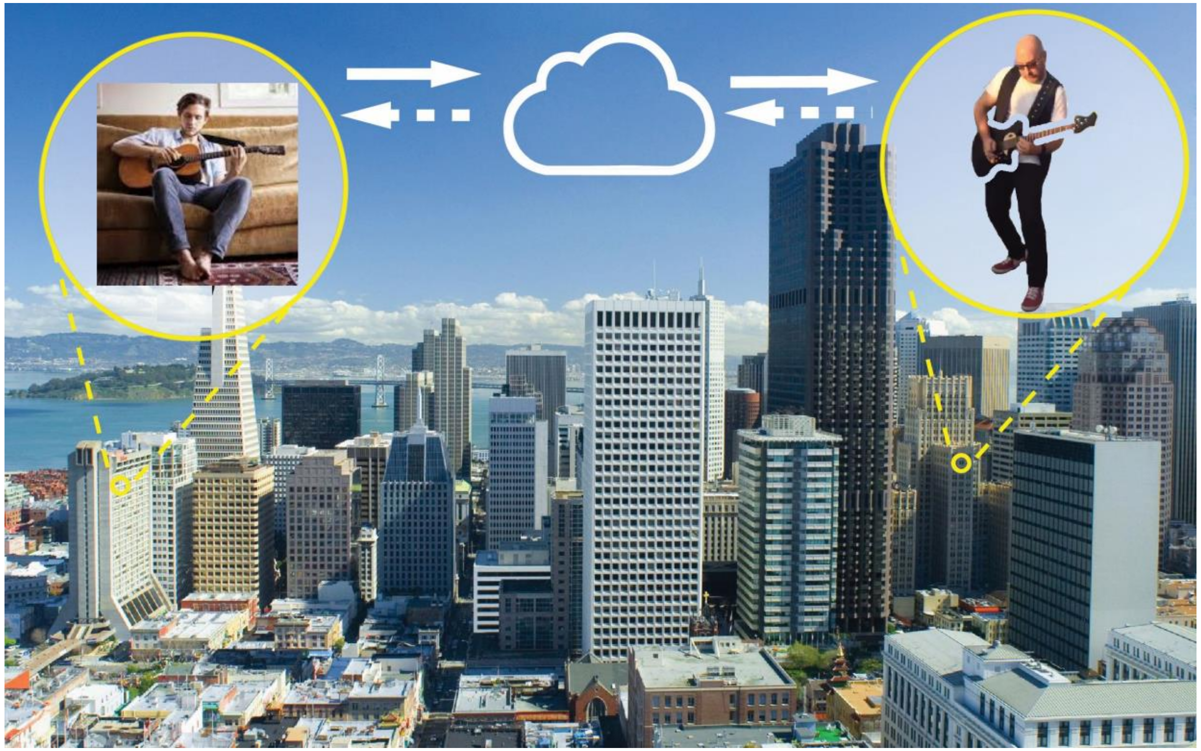
Coordination and Demonstration

- Ericsson will collaborate in the demonstration of the proposed networking methods
- ABB will collaborate in the demonstration of low-latency automation methods
- MIND Music Lab will collaborate in the demonstration of low latency networking for virtual concerts over networks

MIND Music Labs –
Internet of Musical Instruments



www.mindmusiclabs.com

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1M€, 2016-2019

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