Research challenges in Deployment of Wireless sensor and actor networks (WSAN)

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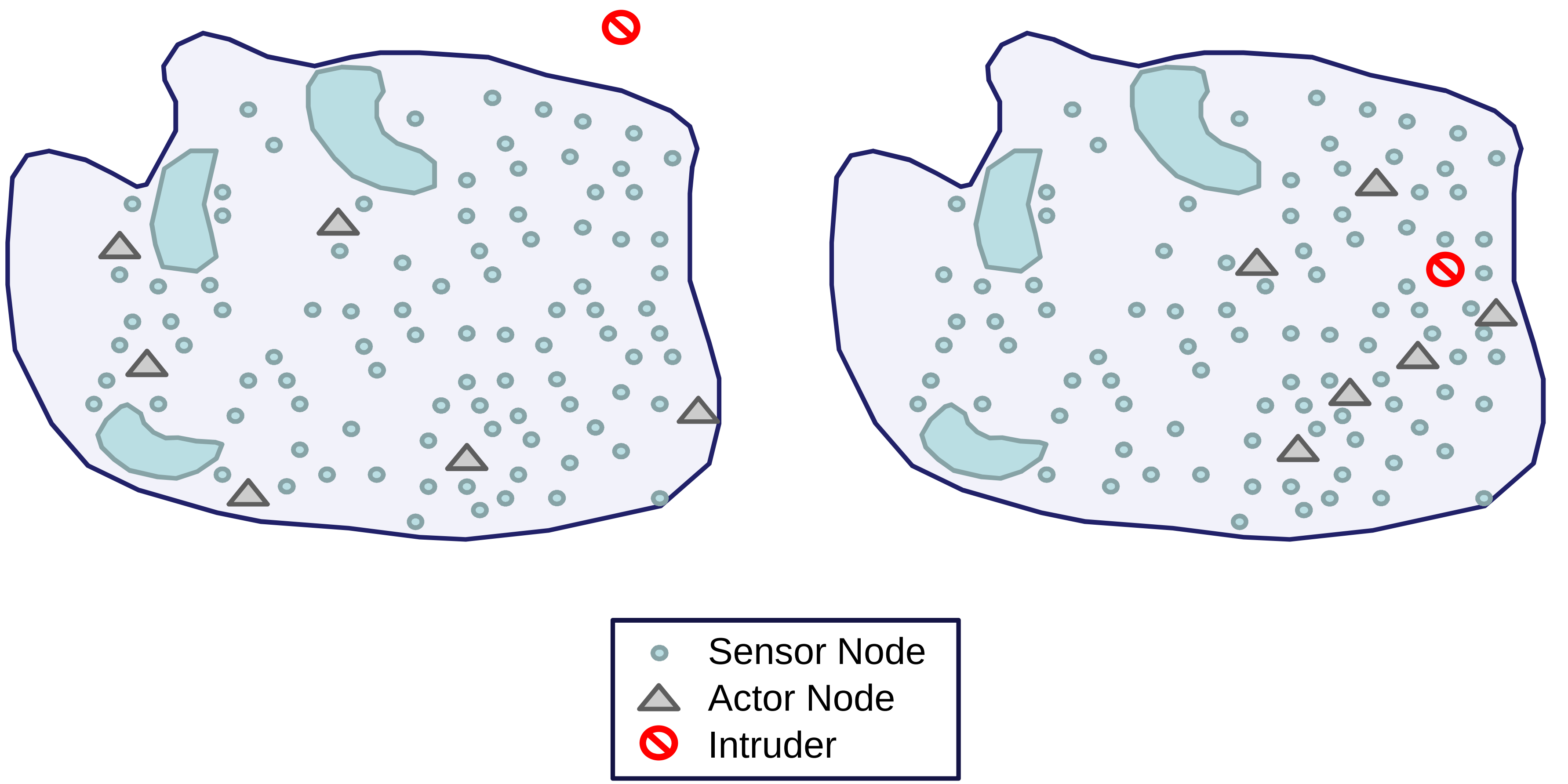
A sample arrangement of distant actors before event detection (left) and as they move towards the event area (right)



New and powerful technology

- We are in the presence of a new and powerful technology called Wireless Sensor and Actor Networks.
- There are many fields where we can apply this technology to develop varied and interesting applications:
  - high security environments, environmental monitoring
  - industrial monitoring, precision agriculture, Medicine
  - smart energy grids, battlefield surveillance
  - microclimate control in buildings, nuclear, biological and chemical attack detection etc.
  - This technology brings the need to develop new frameworks in order to make easier the application developer's task.

Research challenges

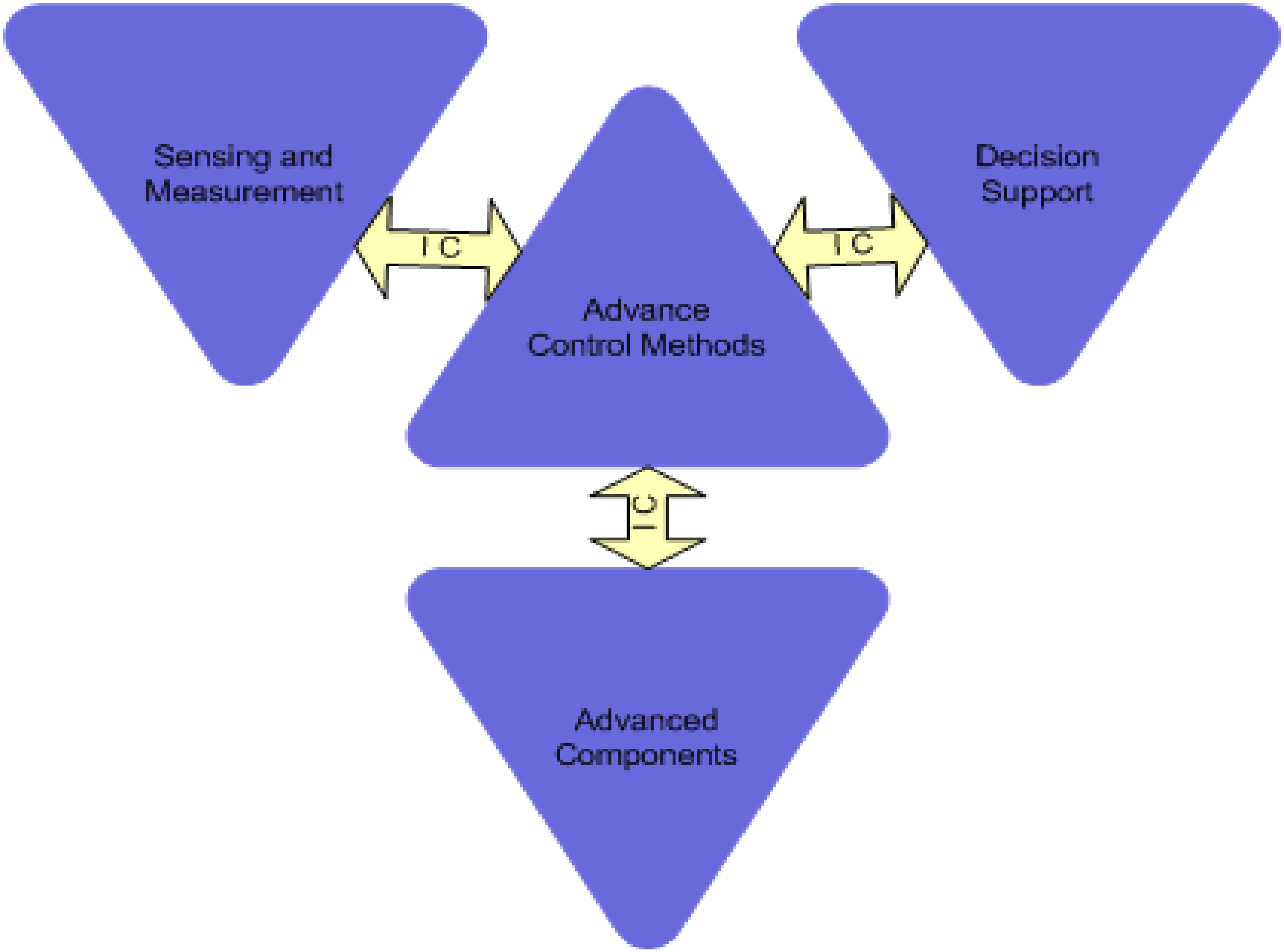
- Despite some existing research in WSAN, **coordination and communication** problems that arise in WSANs due to the coexistence of sensors and actors are yet to be investigated.
- **Coordination:** Unlike WSNs where the central entity (i.e., sink) performs the functions of data collection and coordination, in WSANs, new networking phenomena called sensor-actor and actor–actor coordination may occur.
- In particular, sensor-actor coordination provides the transmission of event features from sensors to actors.
- After receiving event information, actors need to coordinate with each other in order to make decisions on the most appropriate way to perform the action.
- **Real-time requirement:** WSANs can be seen as a distributed control system designed to timely react to sensor information with an effective action. For this reason, real-time coordination and communication is an important concern in WSANs to guarantee the timely execution of correct actions.
- The **energy efficiency** of network communications is also crucial, since sensors are resource-constrained nodes with a limited battery lifetime. Furthermore, sensor network protocols and algorithms should be scalable and localized, as the number of nodes can be arbitrarily high.

Research challenges in some specific applications

- We are still no where near the production of industrial-grade WSAN software that can be relied upon for **mission critical applications.**
- **The cost of programming, deploying and maintaining WSAN environments is still highly prohibitive due to the lack of industrial tools capable of realizing adaptive WSAN software in a cost effective way.**
- **Next generation WSAN environments as large-scale autonomous systems should:**
  - **be deployed by multiple infrastructure providers**
  - **running multiple applications and**
  - **providing ubiquitous services collaboratively to both stationary and mobile users**

Opportunities and Challenges of Sensor and Actuator Networks (SANETs) in Smart Grid

- Recently, Sensor and Actuator Networks (SANETs) have been recognized as a promising technology that can enhance various aspects of today's electric power systems, including generation, delivery, and utilization, making them a vital component of the next generation electric power system, the smart grid.
- SANETs are expected to be heterogeneous networks, comprised of a large number of networked nodes, each serving the role of a sensor, an actuator or both. SANETs integrate the tasks of remote sensing and actuation, the process of controlling a physical system by setting values for parameters of interest.



Sensing and Measurement
Decision Support
IC
IC
Advance Control Methods
IC
Advanced Components

Smart Grids - vision

- To transform the electricity grid into a flexible, resilient and collaborative network using intelligent sensors, advanced communications, information management and control.
- The main benefits of this vision are increased energy efficiency via better match of supply and demand and improved security and reliability via fast and effective response to energy shortages and catastrophic events.

End-to-End Network Measurements

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End-to-End Network Measurements Empower End Users

- Estimating end-to-end path conditions (congestion, error losses, delay, etc.)
- Can help in improving QoS and network utilization
- Can help in verifying service level agreement (SLA) with ISP

Advances and Progress

- Passive and Active Probing Techniques
- Multipath Technology supported by advances in;
  a. Variuos MAC layer interfaces
  b. Multipath routing
  c. Transport layer protocols (such as SCTP multihoming capabilities
- Increase in multicast traffic and the need for end user invovlment in QoS

End-to-End Parameters

- Bottleneck link bandwidth
- Every link capacity (and preferably available capacity)
- End-to-end delay and queuing delay

Possible Actions

- Receiver sends feedback control message to the sender to adjust traffic parameters
- Receiver can independently decide to join the connection or n't, or to join a different multicast group.

Packet Pair Probing

- Measuring the dispersion at the destination will lead to the calculation of the bottleneck link bandwidth and eventually to the right admission control decision
- Thus at the receiver side,
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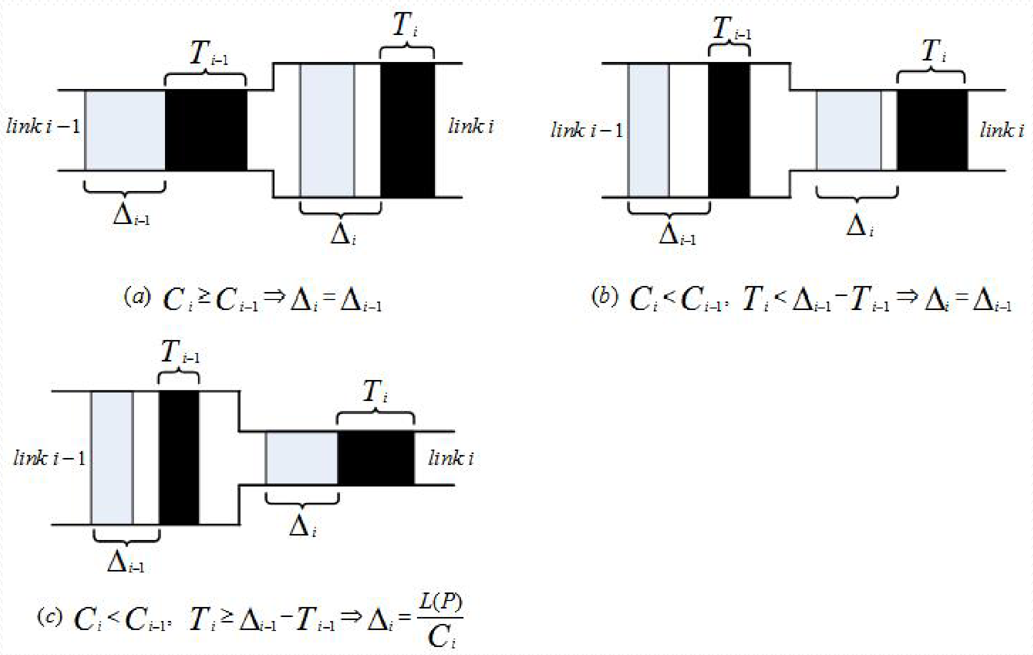
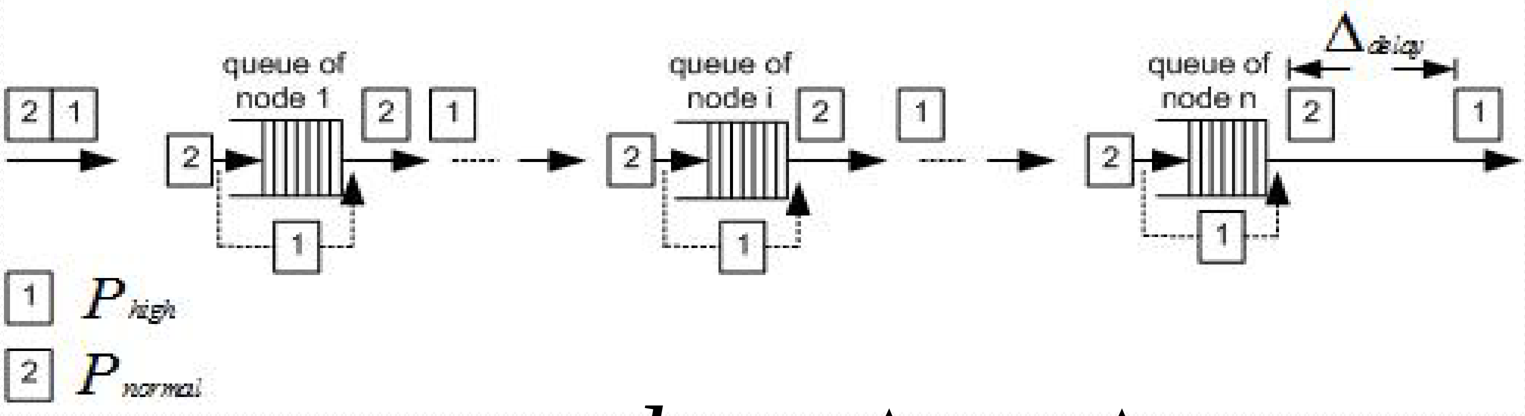
$$\Delta_n = \frac{L(P)}{C_{\min}} \Rightarrow C_{\min} = \frac{L(P)}{\Delta_n}$$



Measure End-to-End Queuing delay

- Queuing delay reflects the path current utilization.
- Packets with different priorities will suffer different network delays along the path. We evaluate the queuing delay based on the dispersion between those packets.



$$d_{queue} = \Delta_{delay} - \Delta_{C_{\min}}$$

Challenges in Deploying Novel Systems and Networks

IARIA ICSNC Panel

Nice, France, August 23, 2010

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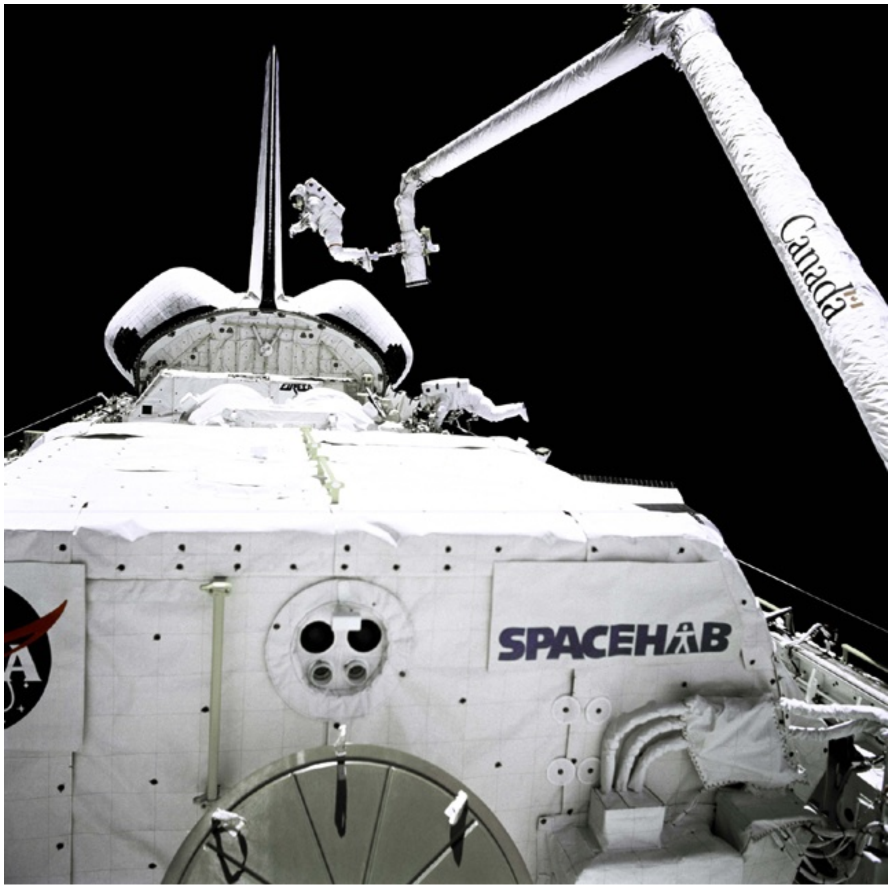
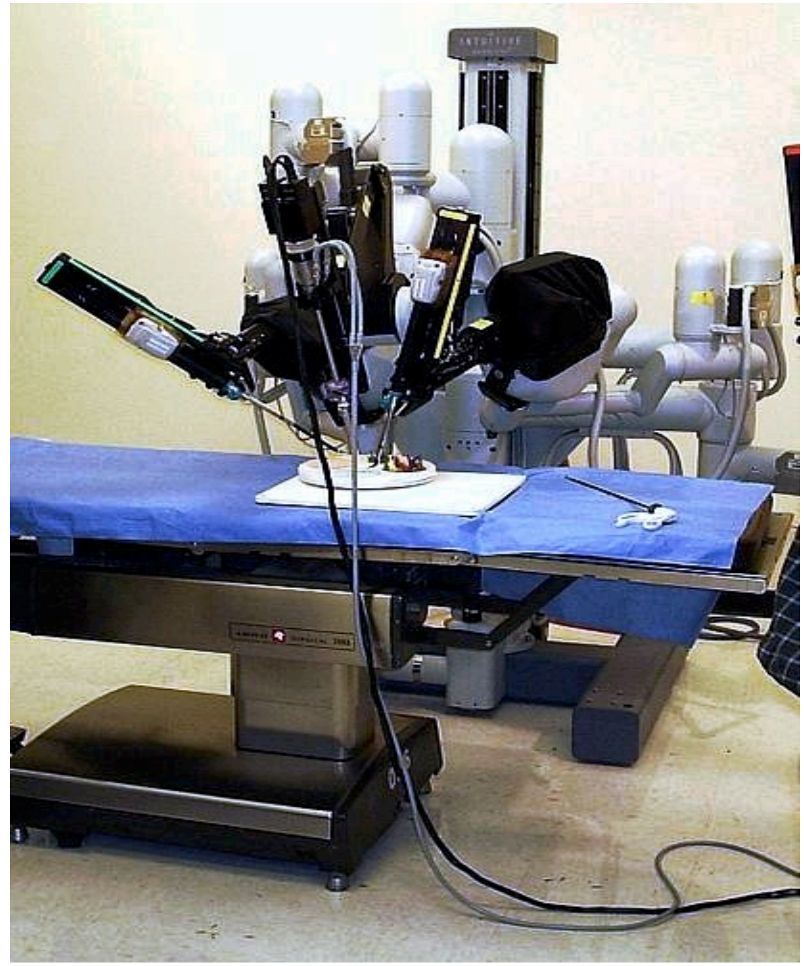
New End-Services - Telerobotics



Space Shuttle Robotic arm



Surgical Robot

- Robots have come a long was since Isaac Asimov's 1951 text 'I, Robot'

Rotterdam Shipyard - Robotics

- Rotterdam Shipyard processes millions of shipping containers annually using robotics, computers and specialized networks for QoS

The Challenge: Robotics Needs QoS

- Challenges:
- Does 'Perfect-QoS' in a large network like the Best-Effort Internet even exist ?
- Over 32,000 papers in IEEE digital Library dealing with some aspect of QoS in 2010, without a formal definition or a proof of existence for 'Perfect-QoS' !

?

- If it does exist, is it achievable ?
- If it is achievable, how much will it cost ?
- If it is achievable, who will pay for it ?

Technical Challenges: Complexity and Scalability

- For ‘Perfect’ QoS, many NP-Hard problems stand in the way:
- ‘Perfect’ zero-jitter packet scheduling is NP-Hard
- ‘Perfect’ Scheduling in Wireless Mesh Networks is NP-Hard
- ‘Perfect’ routing (100% capacity) is NP-Hard
- ‘Perfect’ problems are too Complex to solve, too Complex to Scale

- Are ‘Essentially-Perfect’ QoS solutions possible ?
- If so, how much would they cost ?

Future Internet Assembly

- Many countries world-wide are embarking on research to define the ‘Future Internet’
- European Union ‘Future Internet for Future Europe’ defines several key features of a Future Internet: advanced health care, mobility and energy efficiency
- What will the Future Internet look like ?
- Will it have the same Best-Effort service model of the current legacy Internet, relying on significant over-provisioning to provide poor QoS guarantees ?
- Will QoS for telerobotics be supported for Future Internet services: telerobotic assisted surgery, telerobotic controlled transportation, telerobotic-assisted manufacturing and shipping ?

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Conclusions

- Challenges stand in the way of deploying a novel system, such as Perfect QoS, over a legacy network i.e. Best-Effort Internet
- Does a 'Perfect-QoS' system even exist ?
- Complexity and Scalability are often NP-Hard problems
- Legacy networks like Best-Effort Internet are sufficient for most of today's users: Separate specialized networks used for rigorous QoS; So why fix what isn't broken ?
- Our belief: Adding Essentially-Perfect QoS to the Future Internet is achievable with no cost, and will significantly reduce costs for routers, switches and Future Internet infrastructure !
- One challenge is inertia– why fix what works (sort of) ? There is no risk in remaining idle. This is why telco divestiture occurred !