ROYAL INSTITUTE
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WP2: Wireless networking for control

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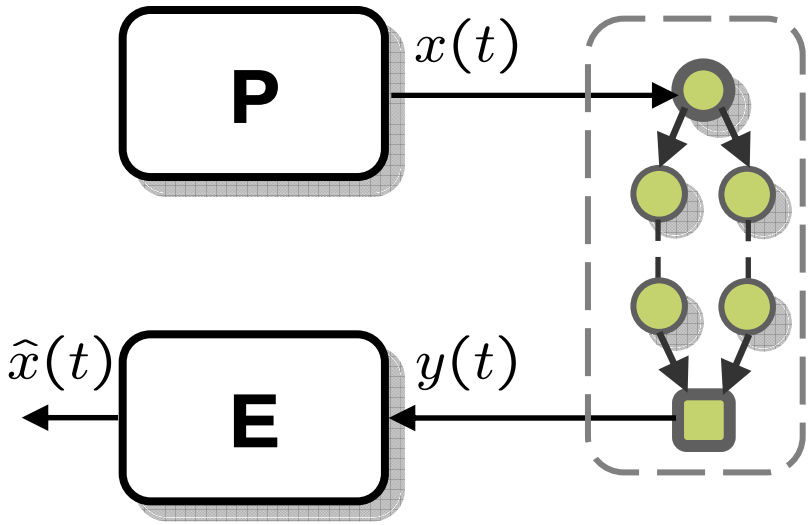
Work

Key outcomes:

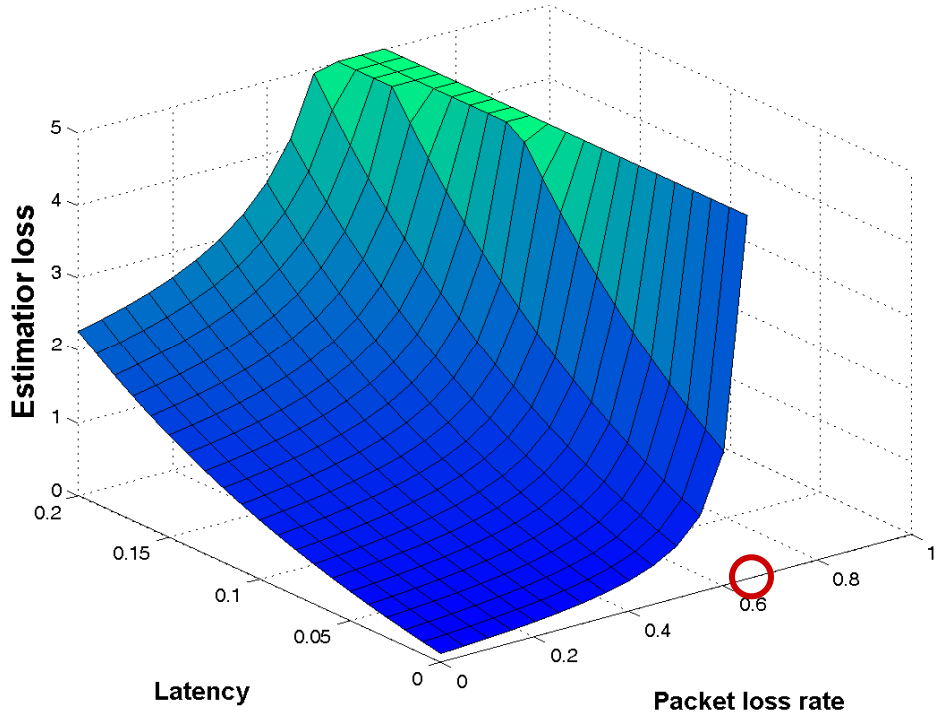
- Link scheduling for WirelessHART networks
  - Latency and channel optimal convergecast
  - Maximum reliability scheduling for hard real-time
- SenzaNET: lightweight self-organizing industrial wireless
- Co-simulation of networked control systems
- In-network processing for distributed estimation

Case study: real-time monitoring



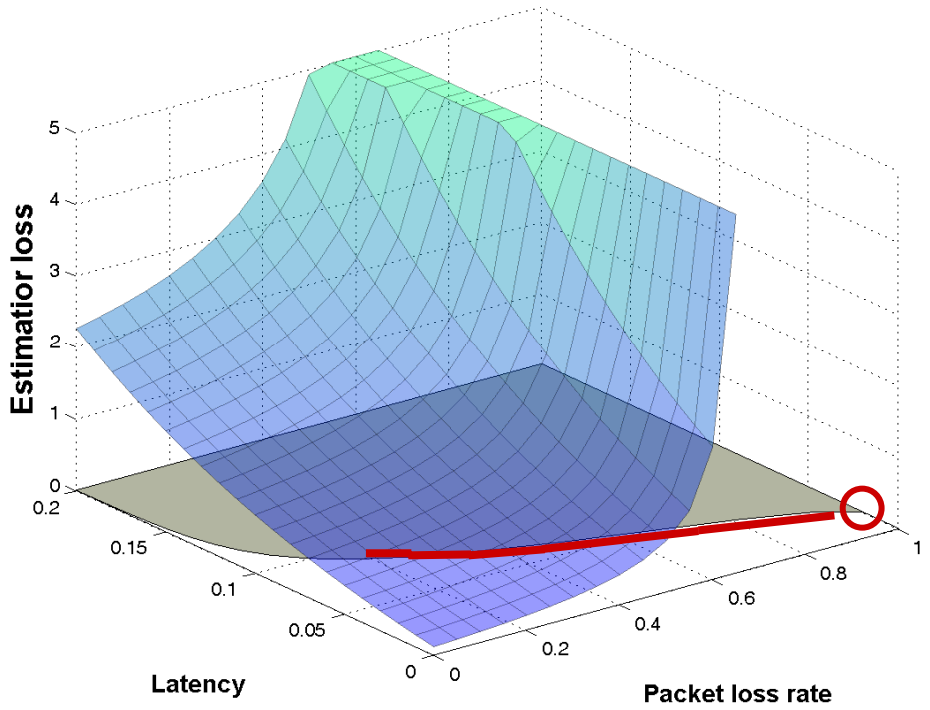
Problem: maintain estimate $\widehat{x}(t)$ of $x(t)$ using sensor stream $y(t)$

Application requirements



Estimator performance as function of latency and loss

What can the network provide?



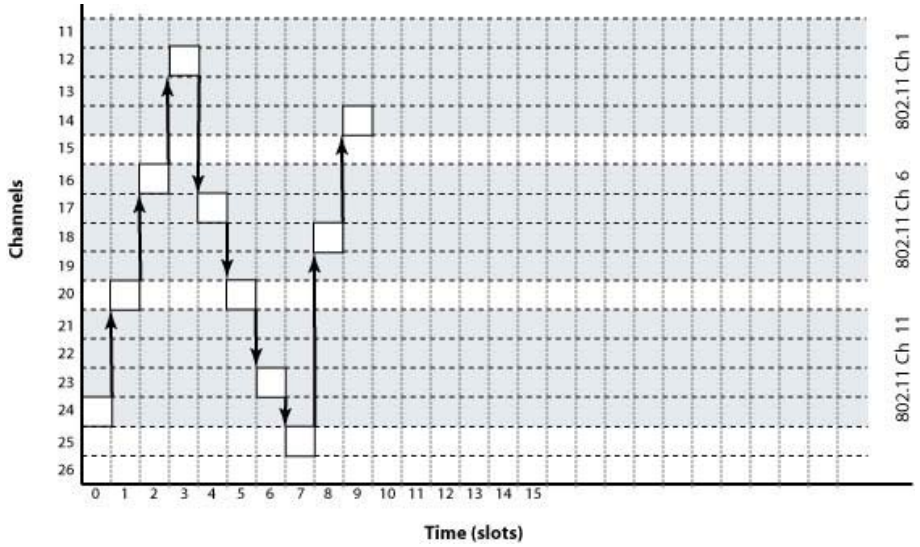
Challenge:

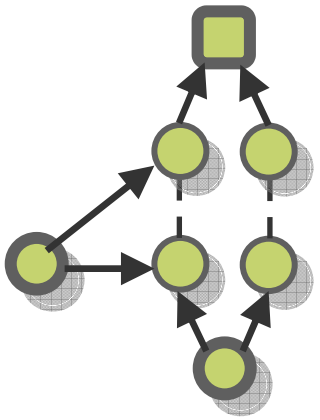
- *Characterize* achievable loss-latency region
- *Design* policies that achieve optimal operation

An abstract *Wireless*HART model

*Wireless*HART characteristics:

- Multi-channel TDMA, no spatial reuse within same channel
- Channel hopping on per-transaction (data+ACK) basis
- Multi-path multi-hop mesh networking
- All traffic goes through gateway.
- Centrally scheduled and managed (by network manager)

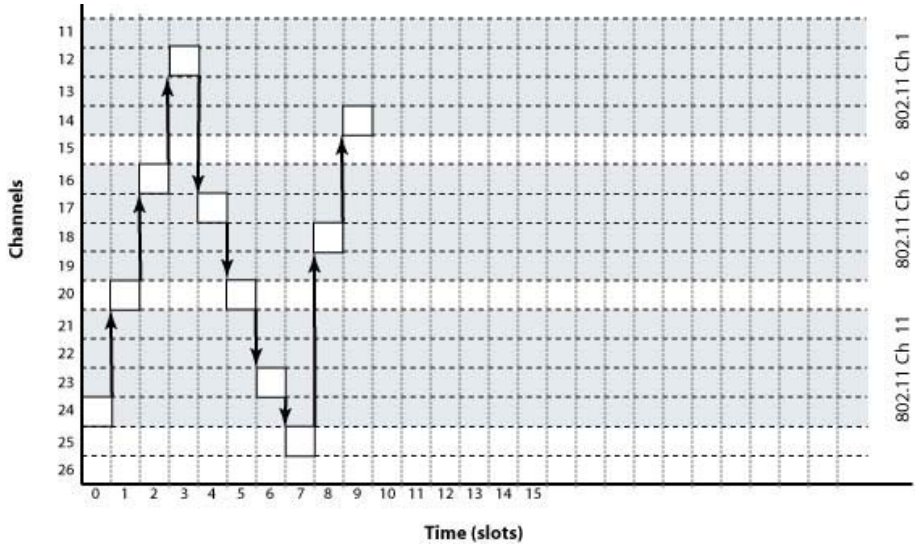


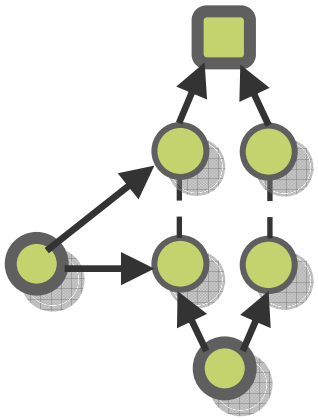


Optimal *Wireless*HART scheduling

Key results

- Mathematical programming formulation (ECC'09)
- Latency and channel-optimal convergecast (WiOpt, ACM ToSN)
- Maximum reliability routing over lossy links (GC'10, CDC'10)
- Controller-scheduling co-design (ETFA'09)





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WIDE end-user panel

Wireless networking for distributed control

Leveraging Power of Wireless®

Key requirements towards a wireless networking protocol

1. Both latency and loss rate must be small and as predictable as possible to facilitate design of control algorithms

2. Full battery-based mesh required to allow for coverage in „difficult“ environments, where e.g. concrete and steel are present

3. Self-organizing capabilities without a centralized Network Manager, as this would increase latency dramatically in case of network re-formation

4. Easy Integration with industrial control systems allowing to control the overall „end-to-end“ latency

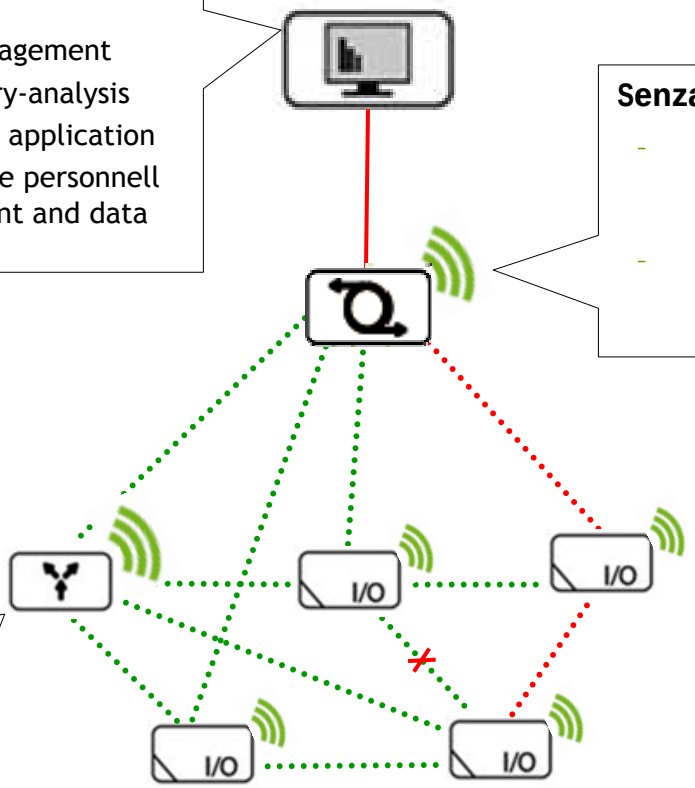
SenzaNET: Platform centered approach

SenzaWMS Software Suite

- Sensor, alarm and data management
- Data visualization and history-analysis
- Standalone system or server application
- Workflow solution for service personnell supporting sensor deployment and data export

SenzaGate

- Provides remote connectivity, time synchronization function, channel hopping sequence
- Additionally supports integration with fieldbus for latency-critical applications



SenzaHub

- Non-sleeping repeater
- Forwards alarms with low latency
- Wireless range extender supporting RF-coverage in complex buildings
- „Wireless backbone“ through chain of SenzaHubs

SenzaBlock Node

- 1st level SenzaBlocks act as “NetworkManager” for their network branch
- Integrated sensors for low-cost nodes
- Industrial interfaces to allow upgrade of existing infrastructures
- Store-and-forward of data from other SenzaBlocks for reliable delivery

Example disruption due to interference

Example of actual mesh data flow

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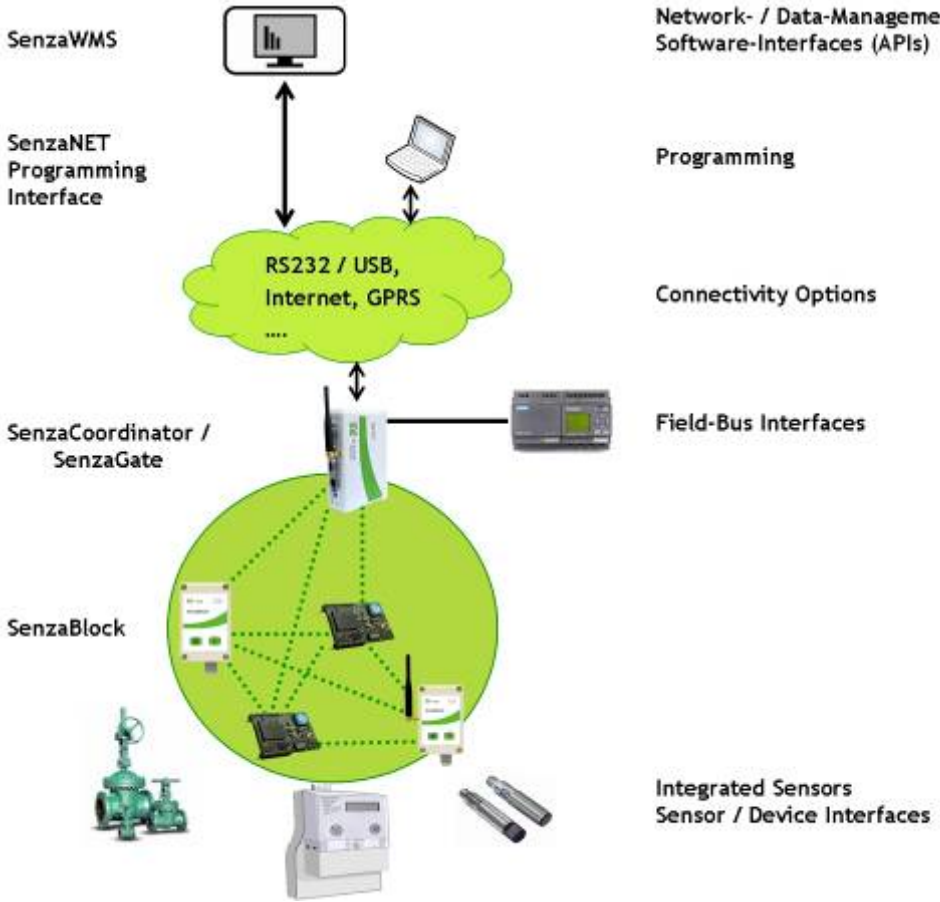
Features and Capabilities Comparison

- **SenzaNET and WirelessHART share many key system/mesh characteristics, whereas SenzaNET allows for faster network formation and re-organization**
- **ZigBee 2006/PRO have fundamentally different traits, and lack the reliability and deterministic latency required for critical monitoring/control applications**

Attribute	SN100 (SenzaNET)	SNH7 (WirelessHART)	ZigBee PRO
Frequency band	2.4 GHz or 868/915 MHz	2.4 GHz	2.4 GHz or 868/915 MHz
Frequency diversity (channel hopping)	Yes (100 msec slots)	Yes (10 msec slots)	No
Time diversity (TDMA)	Yes	Yes	No
Path diversity	No	Yes	No
Acknowledgements and retries	Yes	Yes	Yes
Network reliability (typical)	>99.9%	>99.9%	Not industrial-grade
Low/deterministic network latency	Yes	Yes	No (collisions)
Time synchronization	Yes (≤2 msec)	Yes (≤1 msec)	No
Sleeping routers	Yes	Yes	No
Mesh formation	Fast (seconds)	Slow (minutes)	Fast (seconds)
Stack size	Lightweight	Complex	Complex
Security	128-bit AES encryption	128-bit AES encryption	128-bit AES encryption

Overall view of control system leveraging wireless networking



- **Various options for system integration including SCADA and remote connectivity through GPRS**
- **Low-latency fieldbus-interfacing**
- **Support for commonly used industrial device interfaces to integrate existing field devices**

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