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Selective and Secure Over-The-Air Programming for Wireless Sensor Networks

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Outline

- Introduction
- Security Threats
- Concept of SenSeOP
- Performance Evaluation
- Conclusion

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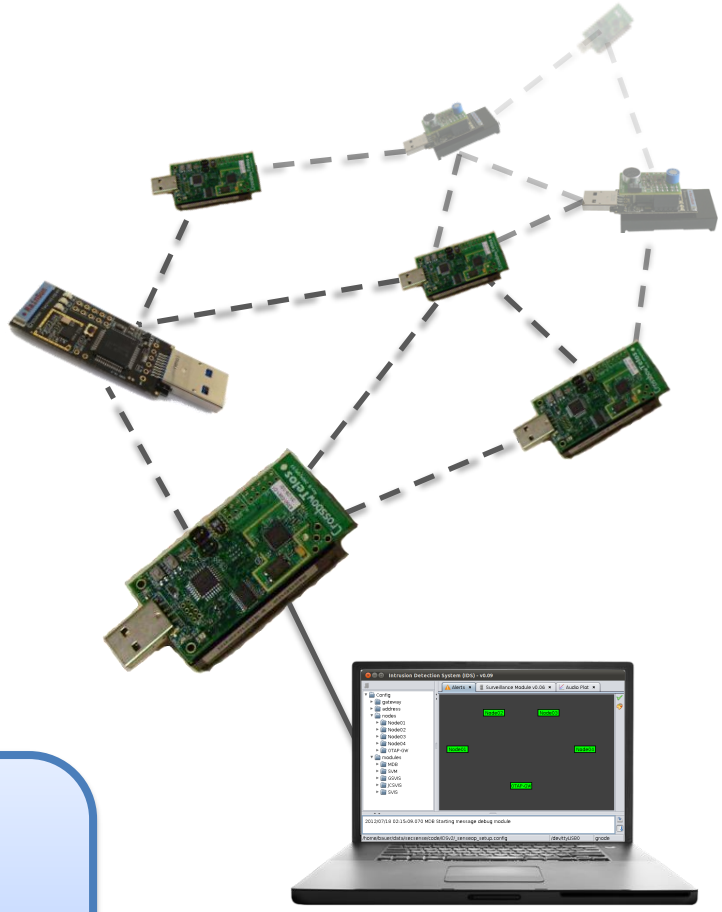
Wireless Sensor Networks (WSNs):

- **plurality of small, cost-effective sensor notes**
- **wireless communication**
- **distributed manner**
- **self-organizing**
- **convergecast traffic to base station**



Challenges:

- **heterogeneous devices**
- **resource constrained**
  (processing power, memory, battery power, network capacity)

Applications:

- **military, industrial, civilian**

Reprogramming WSNs:

- **maintenance, re-tasking, updates, bug fixes**
- **long-life applications, dynamic environments, node failures**

→ Over-The-Air-Programming (OTAP):

- **wireless reprogramming**
- flexible, in-situ **remote maintenance**
- crucial if nodes are **inaccessible** after deployment
- two steps: **transfer** and **booting** of program code

Requirements:

- **reliability**
- **time-efficiency**
- **energy-efficiency**
- **light-weight**
- **selectivity**
- **security**
- **…**

Selective OTAP:

- **group-wise reprogramming** of a specific **subset** of nodes
- essential due to:
  - **heterogeneity of hardware, sensing-, and communication tasks**
  - **spatial dependencies** of sensor nodes

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Without security the WSN is lost!

Type of attacks:

- **Reprogram node attack:**
  - **inside attacker manipulates program code** during transmission
  - **inside attacker injects malicious code** and forces nodes to run that code

  → **capturing of individual nodes / entire WNS**

  → disruption of WSN's functionality

- **Replay attack**
  - **inside attacker uses eavesdropped program code to reprogram arbitrary nodes** with (obsolete) code

- **DoS attacks**
  - against **OTAP service**
  - against **WSN service**

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Deluge:

- default **TinyOS** network programming protocol
- **efficient self-organized, network-wide dissemination**
- **NO selectivity**
- **NO security**

"Security Extensions" of Deluge:

- Dutta et al., Sluice, Seluge, Secure Rateless Deluge
- based on **asymmetric cryptography**
- **authenticity/integrity via digital signatures**

There exists no selective and secure OTAP protocol.

Selective ‘n’ Secure Over-the-air-Programming (SenSeOP):

- based on the threat model
- adopted from **NWProg** (part of BLIP):
  - **message format, image creation/processing routines**
- adopted from **Deluge,** e.g.**:**
  - image **fragmentation scheme, flash memory layout** (multiple slots)
- **simple propagation** instead of complex dissemination of Deluge

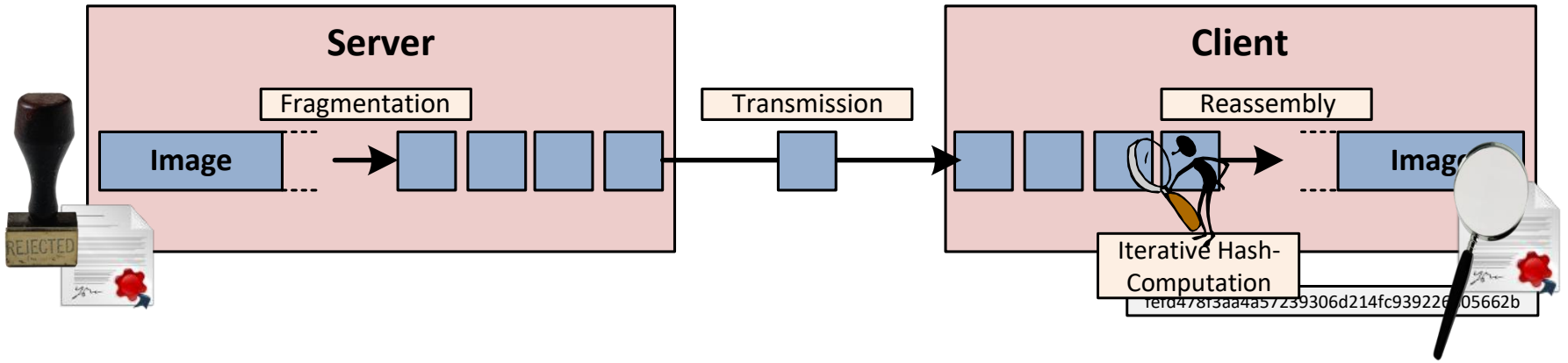
Selectivity:

- **via uni-, multi-cast transmissions** (broadcast available as well)
- **no multicast in IEEE 802.15.4 → explicit multicast (Xcast)**

Intrusion Detection System (IDS): optional IDS integration

Security mechanism:

- **digital signatures (ECC):**
  - nodes can check **integrity** and **authenticity**



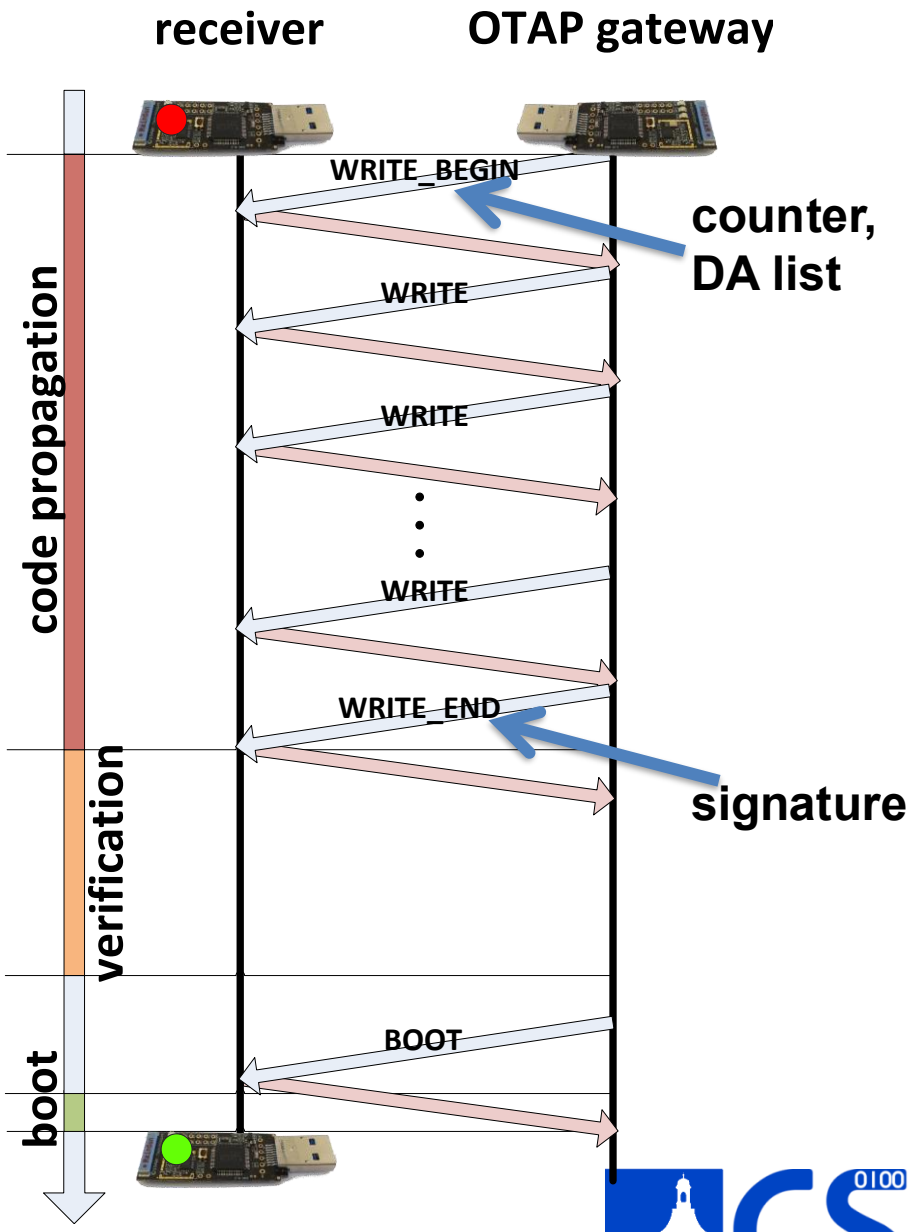
- **invalid signature:**
  - deleting image
  - **locking OTAP module** (primary app not disrupted)
  - **IDS report**
- **asymmetric cryptography**
- **version counter** and **destination address** included in signature

Security features:

- **Reprogram node attack resilience**
- **mitigation of DoS attacks**
- **compromise-tolerant**
- **Replay attack resilience**

OTAP operation phases:

1. **image preparation**
   - signature
   - version counter
   - fragmentation
2. **image propagation**
   - primary app not interrupted
   - timeout triggers IDS alert
3. **image verification**
   - **disruption of primary app**
   - duration: 9-14 sec
   - failure triggers IDS alert
4. **image booting**
   - confirmation with IDS notification



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Performance Evaluation:

- **SenSeOP** implemented in **TinyOS**
  - **TOSBoot**
  - **TinyECC** (192 bit keys, SHA-1 hash)
- performance of **uni-, multi-, broadcast**

Platforms:

- frequency:
- data rate:
- max. payload size:

→ **# packets for OTAP**

TelosB

- 2.4 GHz
- 250 kbps
- 114 byte

→ **487 packets**

G-Node

- 868 MHz
- 38.4 kbps
- 52 byte

→ **928 packets**

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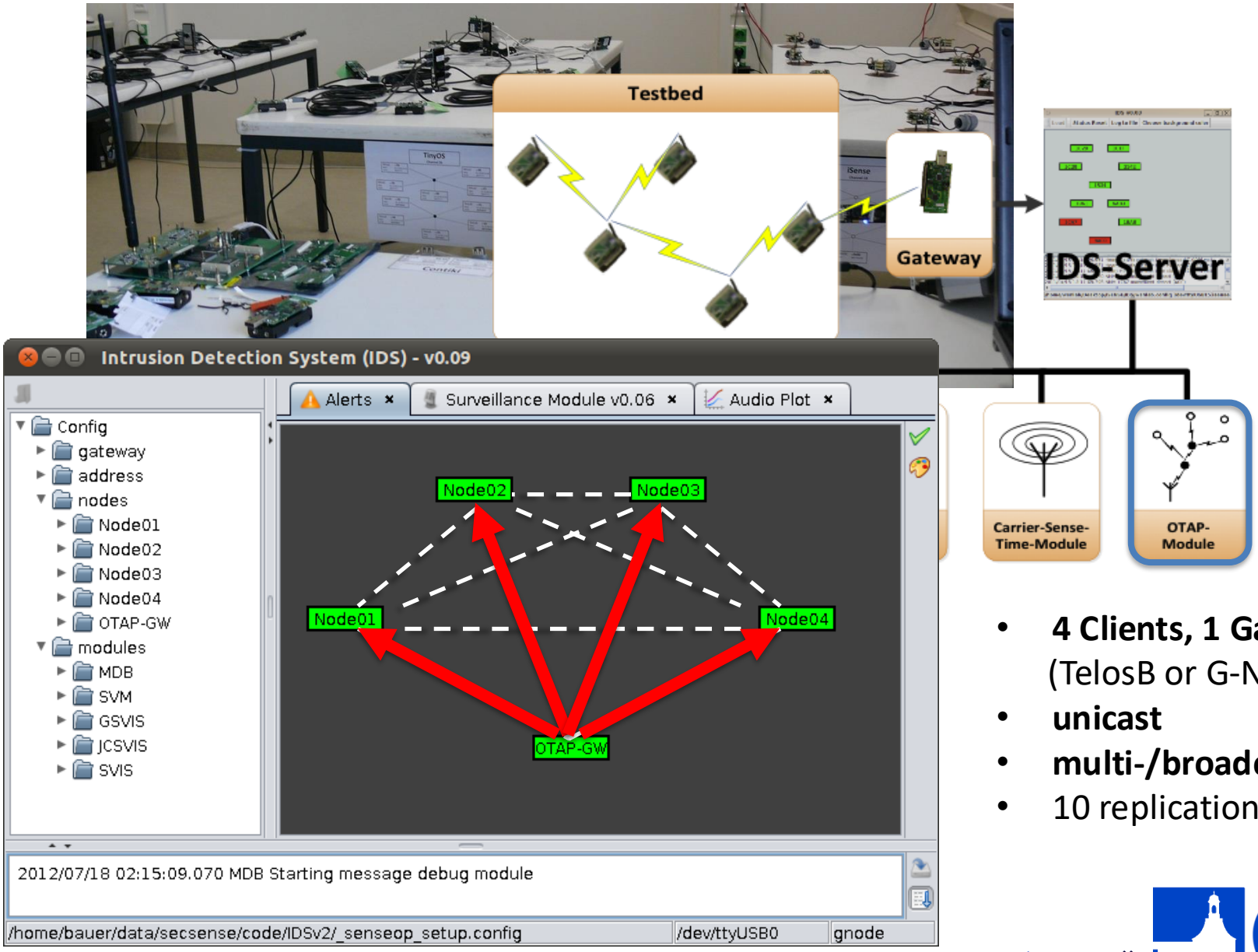

- **4 Clients, 1 Gateway** (TelosB or G-Node)
- **unicast**
- **multi-/broadcast**
- 10 replications

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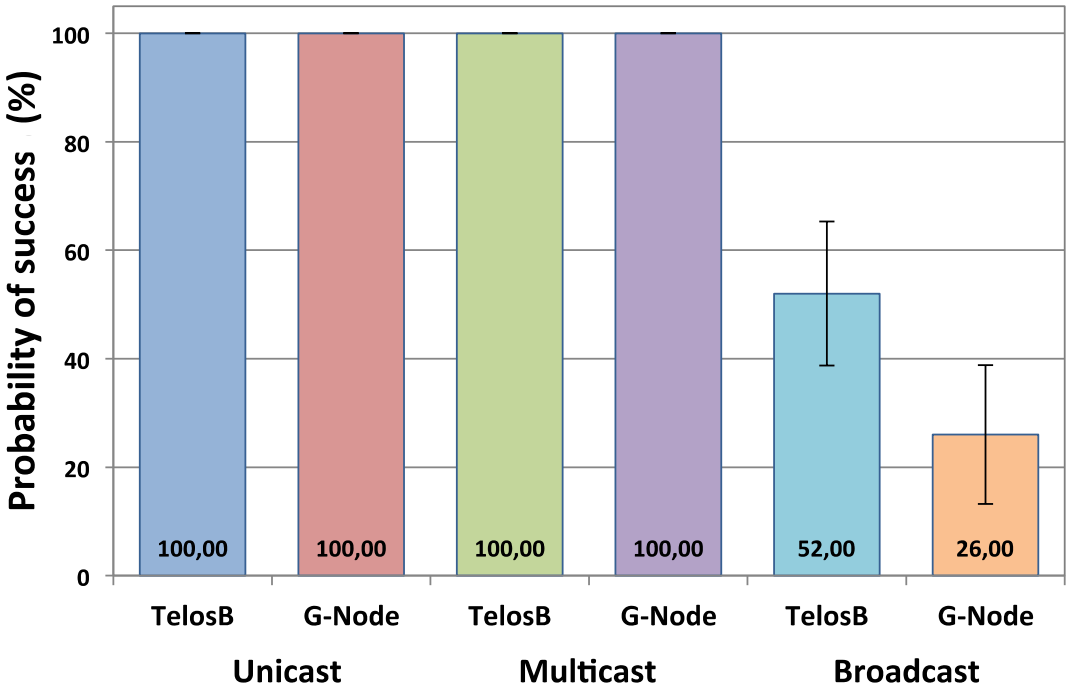
Reliability:

- **success of OTAP transfer**



- **uni- and multicast mode:**
  - **100% reliable** (ACKs)
- **broadcast mode:**
  - unknown # receivers → unknown # ACKs
  - **retransmission only if NO ACK received**

→ **not applicable**

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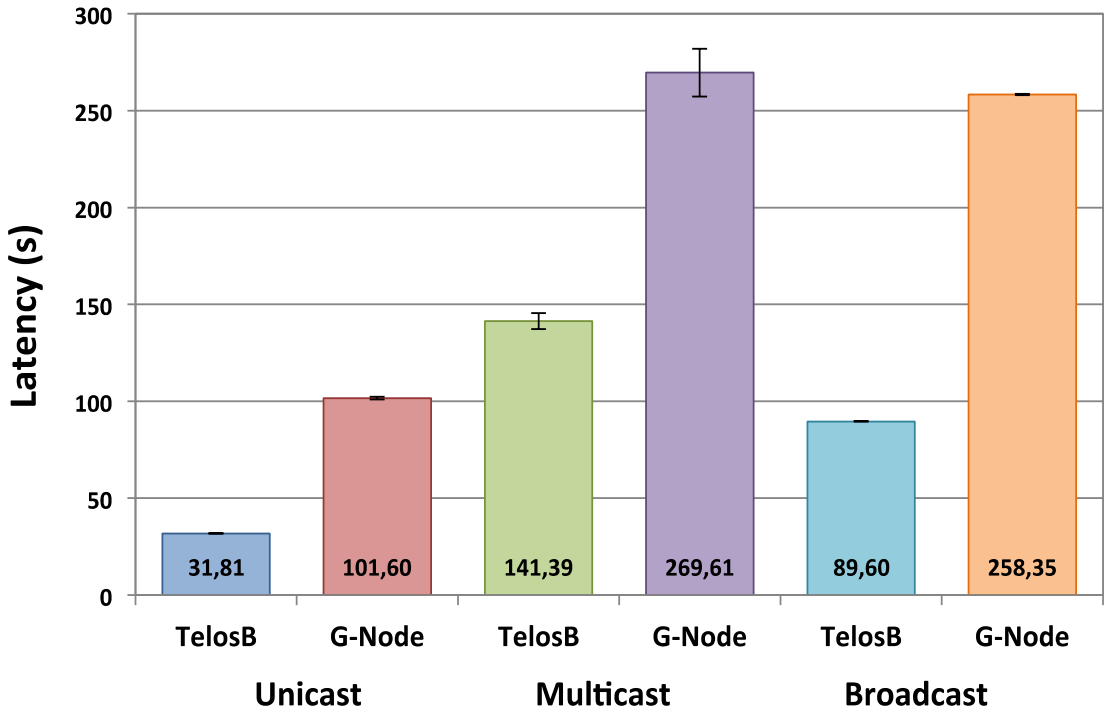
Latency:

- **duration of OTAP transfer**

(w/o verification of signature)

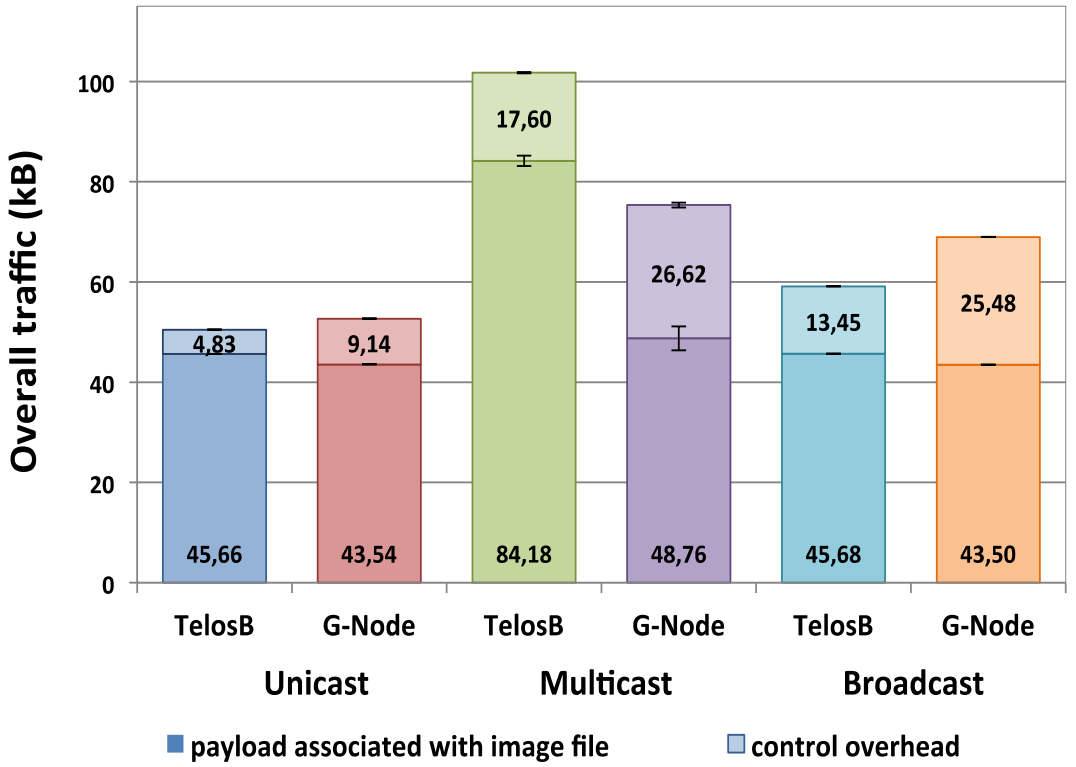


- **multicast mode:**
  - **higher inter-packet buffer required**
    to avoid collisions of multiple replies

→ **no substantial benefit**

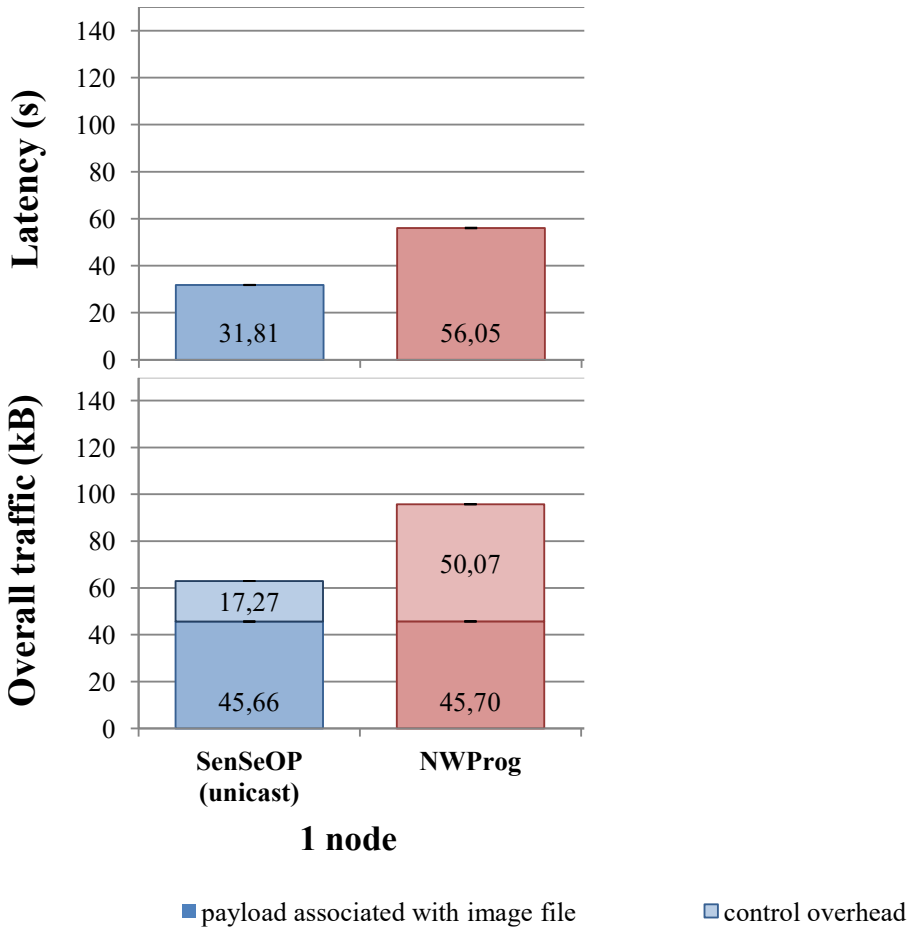
Traffic load:

- including:
  - **control overhead**
  - **data packets** and **retransmits**
- representing **energy usage**



- **multicast mode:**
  - **reduction of network load and energy consumption**

→ **significant benefit**



Future Work:

- **multi-hop support**
- **code size reduction techniques**

- **NWProg: link layer ACKs → less performance** (in this scenario)
- **Deluge:**
  - **higher performance**
  - **less overhead** due to **selective ACKs**

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Conclusion:

- **SenSeOP (selective'n'secure Over-the-air-Programming):**
  - **selectivity** (explicit multicast)
  - **security** (asymmetric cryptography, IDS integration)
  - **light-weight** (simple propagation)

- **Performance Evaluation**
  - **significant benefit of multicast-mode**
    - **energy-efficiency**
    - **reduction of network load**

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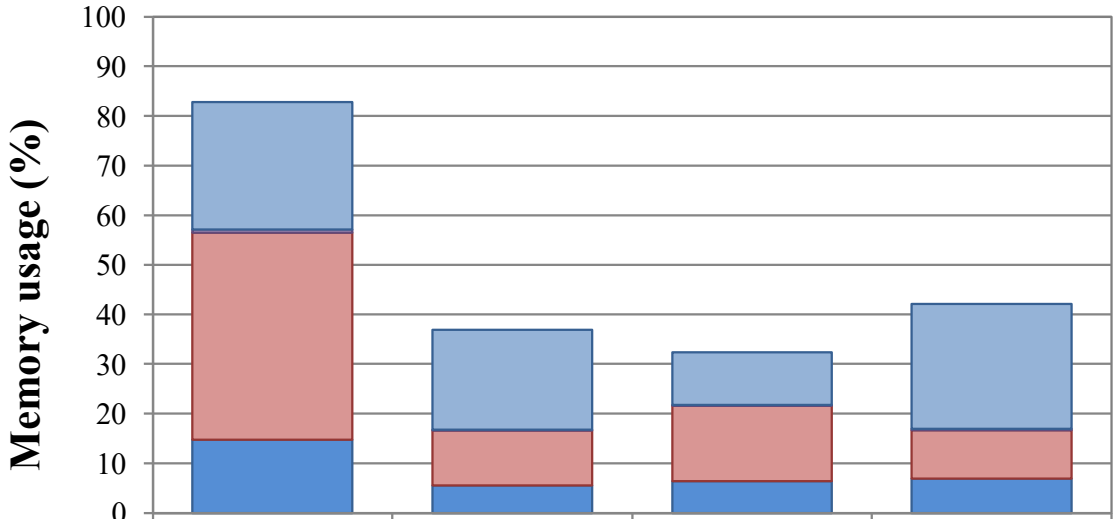
Picture by Nils Aschenbruck



	TelosB ROM	TelosB RAM	G-Node ROM	G-Node RAM
security ext.	25,72	20,06	10,57	25,12
multicast ext.	0,65	0,23	0,24	0,27
OTAP	41,75	11,04	15,22	9,74
core system	14,67	5,53	6,33	6,96

TelosB:
48 kB ROM
10 kB RAM

G-Node:
116 kB ROM
8 kB RAM

- **inherent memory demand:**
  - **OTAP module** (TOSBoot)
  - **Security extension** (TinyECC)
- **however:**
  - many components can be **reused** by primary app
    → **little additional code size**

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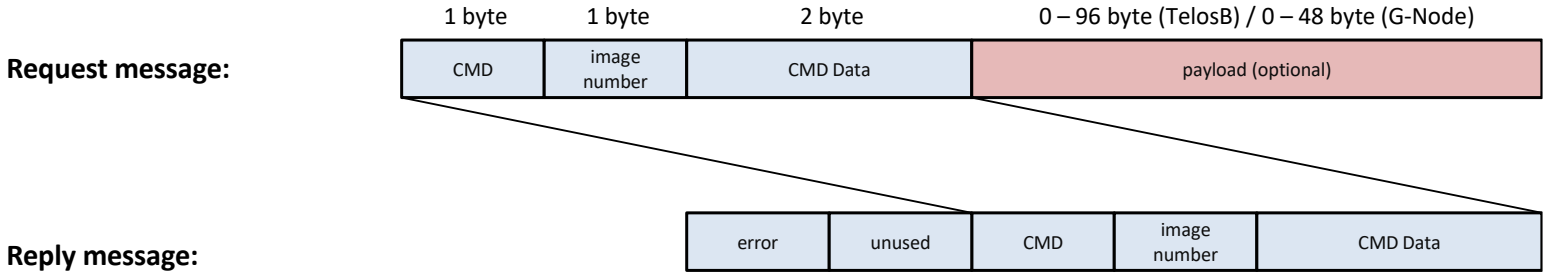
Message format (adopted from NWProg):



Reliability:

- **ARQ mechanism**
  (ACKs, Timeouts)

Security:

- **additional packets**
- additional **IDS alert messages**

CMD	Image-Slot	CMD Data	Payload
erase	{0,1}	--	DA list
boot	{0,1}	time	DA list
reboot	--	time	DA list
write	{0,1}	position	**data**
write_begin	{0,1}	**counter**	**DA list**
write_end	{0,1}	--	**signature**