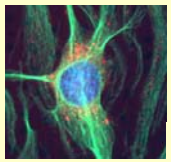
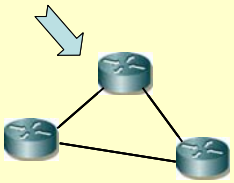
Locality Driven Congestion Control in Self-Organizing Wireless Sensor Networks



Bio-inspired Networking



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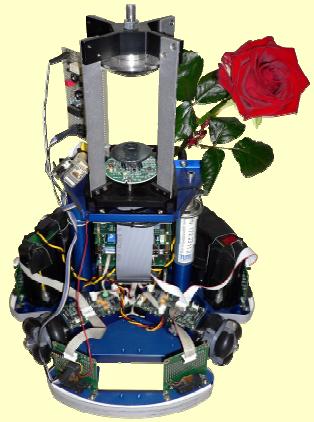
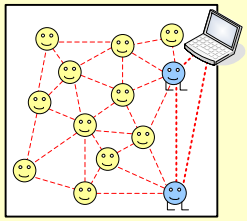


Outline

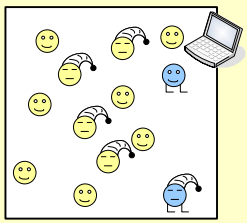
- Research Projects and Objectives
  - ROSES (RObot assisted SEnsor networkS)
  - BioNeting (Bio-inspired Networking)
- Congestion Control in Ad Hoc Networks
  - Data dissemination
  - Congestion control
  - First enhancements
- Locality driven congestion control
- Conclusions

ROSES - RObot assisted SEnsor networkS

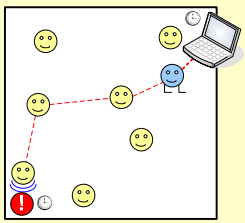
Research Goals



self-organization

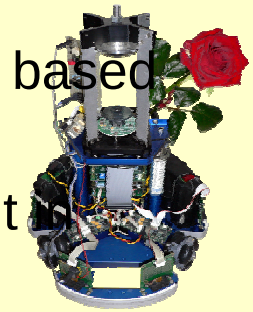


energy awareness



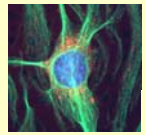
response time

- Energy efficient operation, communication, and navigation
- Sensor network assisted localization and navigation of the robots
- Utilization of the robots as a communication relay between a sensor network and a global network
- Quality of service aware communication in heterogeneous mobile networks with dynamic topology
- Optimized task allocation and communication based on application and energy constraints
- Secure communication and data management in mobile sensor networks

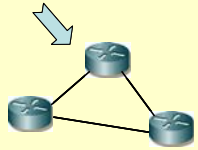


BioNeting - Bio-inspired Networking

- **Concepts**
  - Mapping of mechanisms from cellular and molecular biology to networking architectures
  - Study of large scale networks
  - Analyzing the internal functions of network components as well as their interactions in comparison with cellular systems and the associated intra- and inter-cellular signaling pathways



Bio-inspired Networking



- **Research Goals**
  - Analysis of similarities of computer networks and cellular systems
  - Deduction of new concepts for behavior patterns of network nodes
  - Increasing the efficiency of individual subsystems

Data Dissemination in SN

- Assumptions for typical sensor networks
  - Large amounts of participating nodes
  - Each node transmits its measurement data with the same constant data rate
  - During fast environmental changes (→ emergencies), this data rate may show high bursts

- Data dissemination
  - Address centric routing and data forwarding

    → due to scalability issues infrequently used in SN
  - Data-centric message forwarding, e.g. flooding, gossiping, probabilistic/weighted forwarding, diffusion techniques

    → usually lack congestion control mechanisms

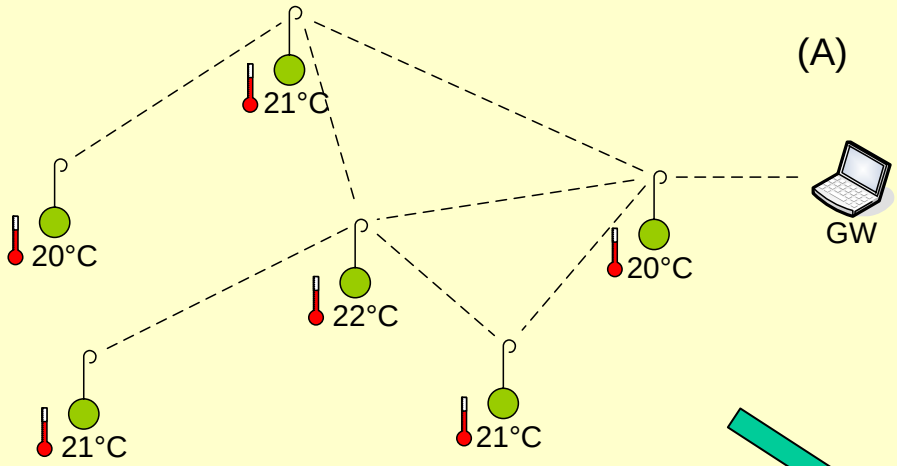
Congestion Control in SN

- State of the art
  - End-to-end – flow based, relying on window mechanisms or feedback information
  - Path-based – flow based, using congestion signaling along the data path towards the sender
  - Hop-by-hop – detection information is signaled to all neighboring nodes

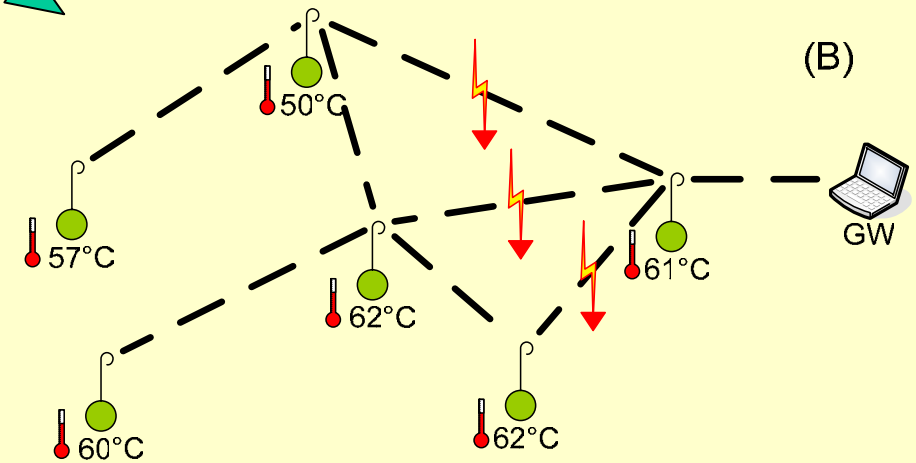
  - All approaches are based on Internet technology
    → require unambiguous addressing information
    → require defined data paths between sender and receiver

  - Few of these requirements can be granted in typical wireless sensor networks

Reasons for Congestion in SN

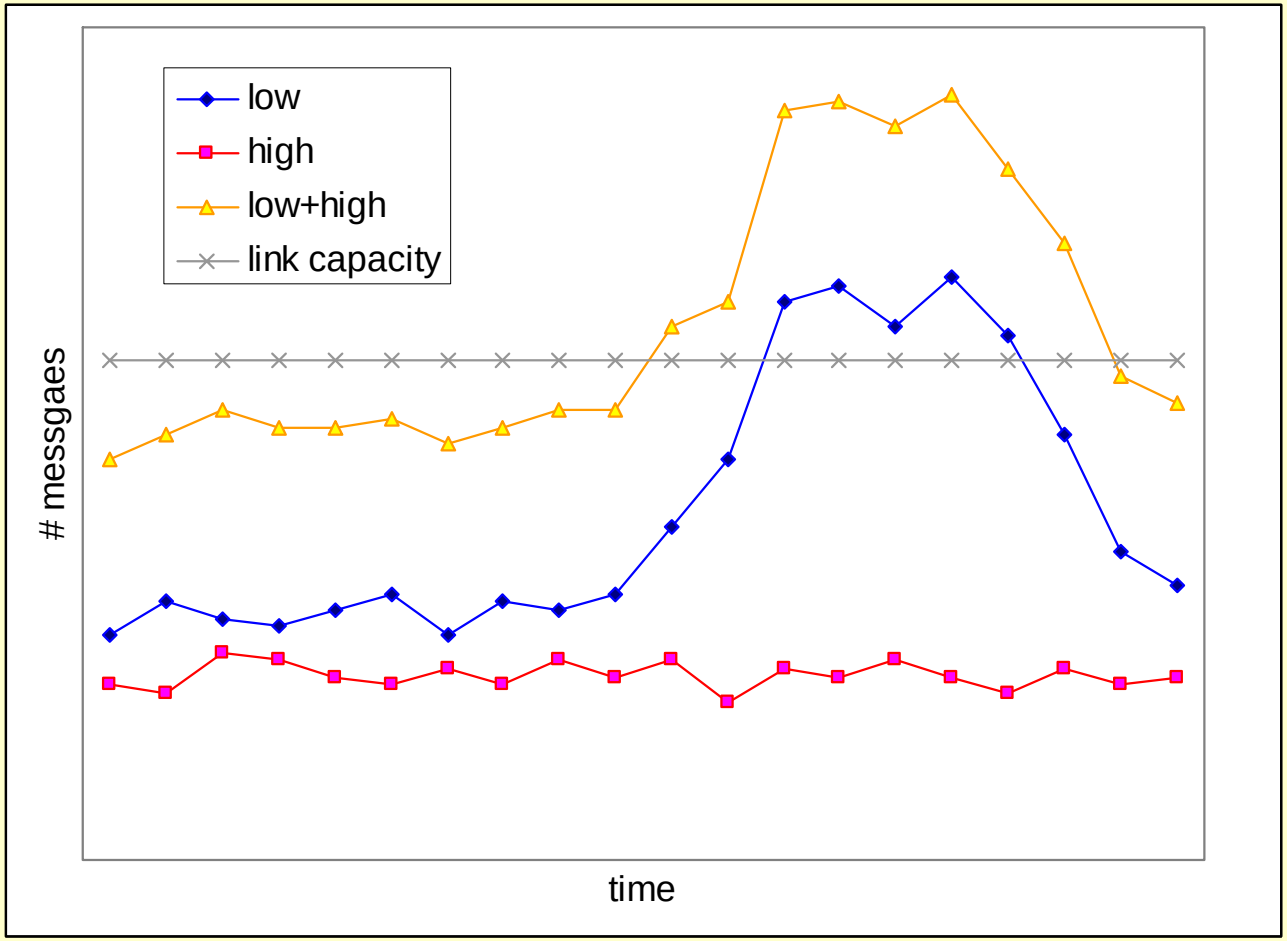


Congestion due to changes in the environment



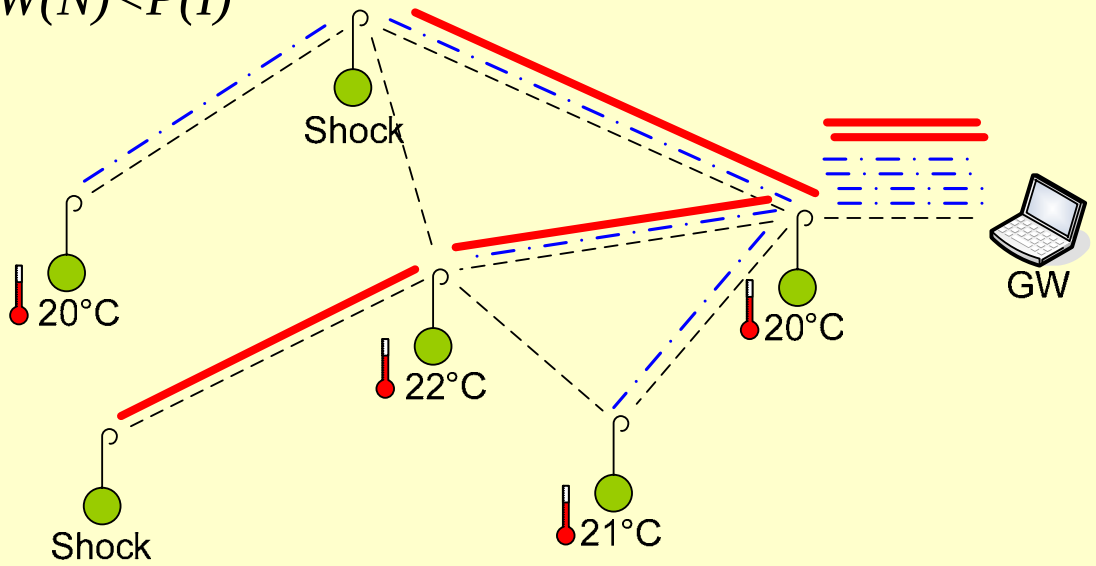
Similar or even worse situations can be expected in heterogeneous network environments employing different sensors for multiple simultaneous tasks!

Congestion Behavior



First Enhancements

- Weighted / probabilistic distribution [Dressler2005]
  1. assign importance *I* to each event
  2. calculate priority *P(I)* describing the distribution range
  3. for all neighboring nodes *Nn* and previously known remote accessible nodes *Nr*, calculate an exponentially distributed weighting *W(N)*
  4. forward message if *W(N)<P(I)*



Locality Driven Congestion Control

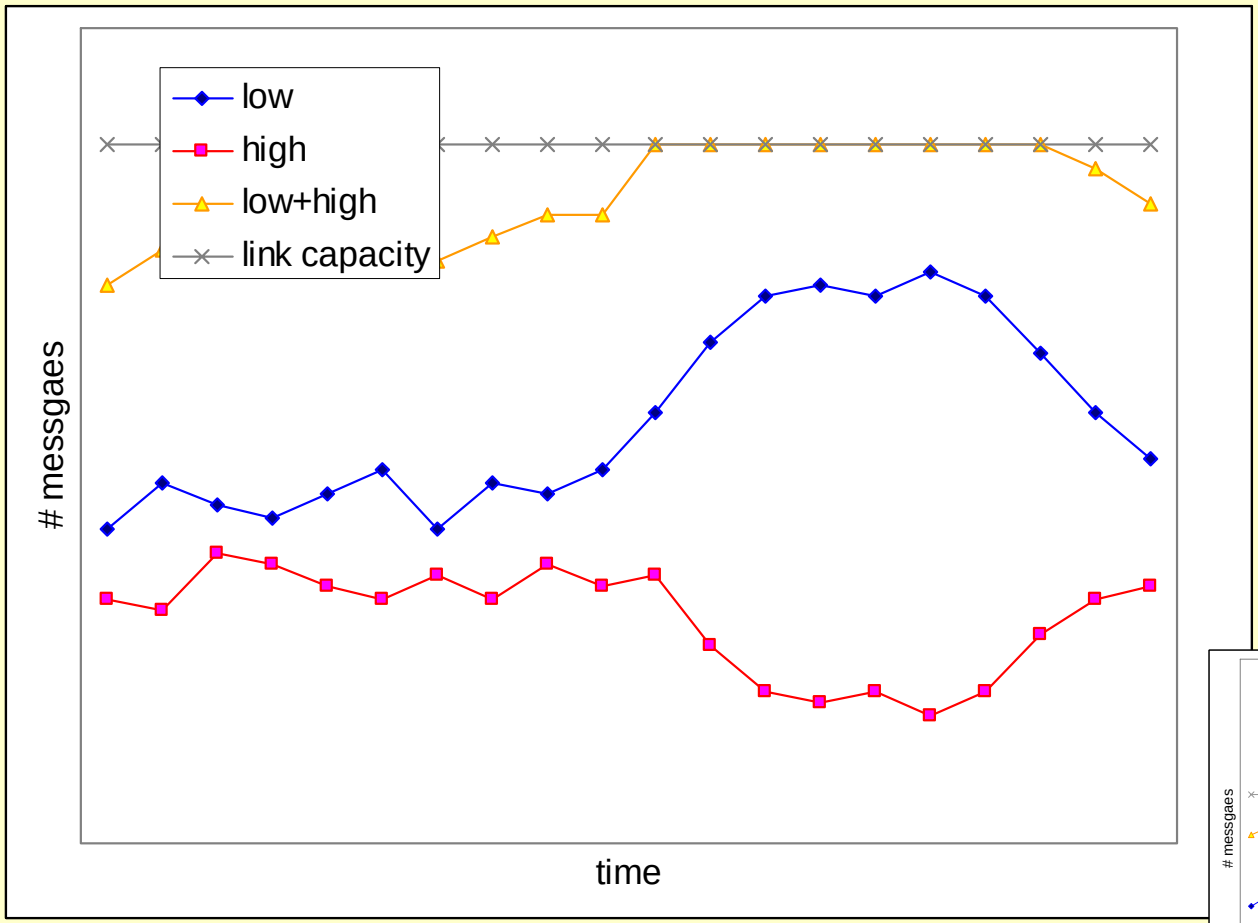
- Basic requirements
  - To maintain control even if some links get temporarily saturated
  - To give priority to important messages
  - To prevent starvation of particular transmissions
- Algorithm
  - Based on the number of successfully received messages N during the last time interval T

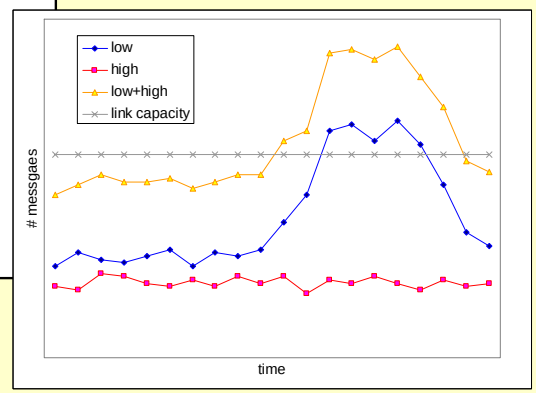
```
For each message M
    update message counter N(M,T)
    identify importance factor I_M
    calculate probability P(N,I_M)
    if exponentialDist(P,T)=TRUE
          forward message M
```

Locality Driven Congestion Control

1. The arrival rate λ of messages is used for estimating the congestion. The counter N, i.e. the number of messages received in the last interval T, represents this rate. It is updated with every received message M as a function of M and T.
2. Each message contains an importance factor I_M. It is used as the primary decision element for congestion control, i.e. the forwarding probability.
3. Using I_M and N, the forwarding probability $P(N,I_M)$ is calculated. This function is used to control the number of messages per time based on their priority.
4. Finally, an exponential distribution of outgoing messages is calculated in order to ensure that P is large enough to match the parameters of the outgoing channel. Thus, the saturation of the outgoing link is included to transmit as much messages as possible but to prevent congestion on this forwarding channel.
5. Based on the wireless transmission, the system is able to observe the saturation of the radio link. Thus, the parameters can be directly adapted to current situation.

Simulation Results





Conclusions and Outlook

- General requirements and solution space
  - Self-organizing and adaptive communication mechanisms are required for large-scale sensor networks
  - Studies of biological mechanisms for self-organization such as the signaling pathways in cell and molecular biology provide high potentials
- Locality driven congestion control provides the following features
  - Based on locally available information only
  - → highly scalable
  - → no further control overhead / message overhead
  - Adaptive to changing network conditions
  - Features priority messages
  - No starvation of less important transmissions
- Next steps
  - Ongoing implementation of the algorithm in a lab environment consisting of Mica2 motes to compare experimental measurements with analytical and simulative results

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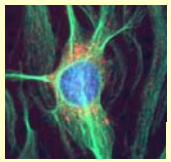

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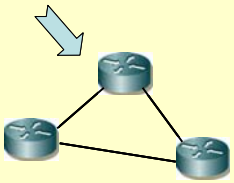

Any Questions?