**Computer and Communication Systems
(Lehrstuhl für Technische Informatik)**

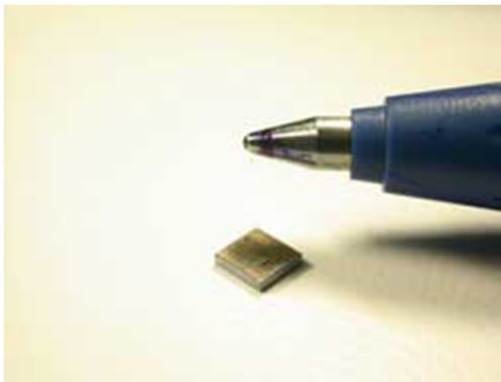# Monitoring Bats in Outdoor Environments: Strong Needs for Energy-Efficient Machine-to-Machine Communication
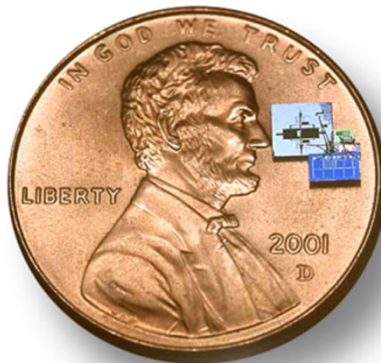
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From WSN to IoT to CPS

- Wireless Sensor Network (WSN)
  - Hundreds of networked sensor nodes, composed of sensors + processing/storage + wireless comm. + battery
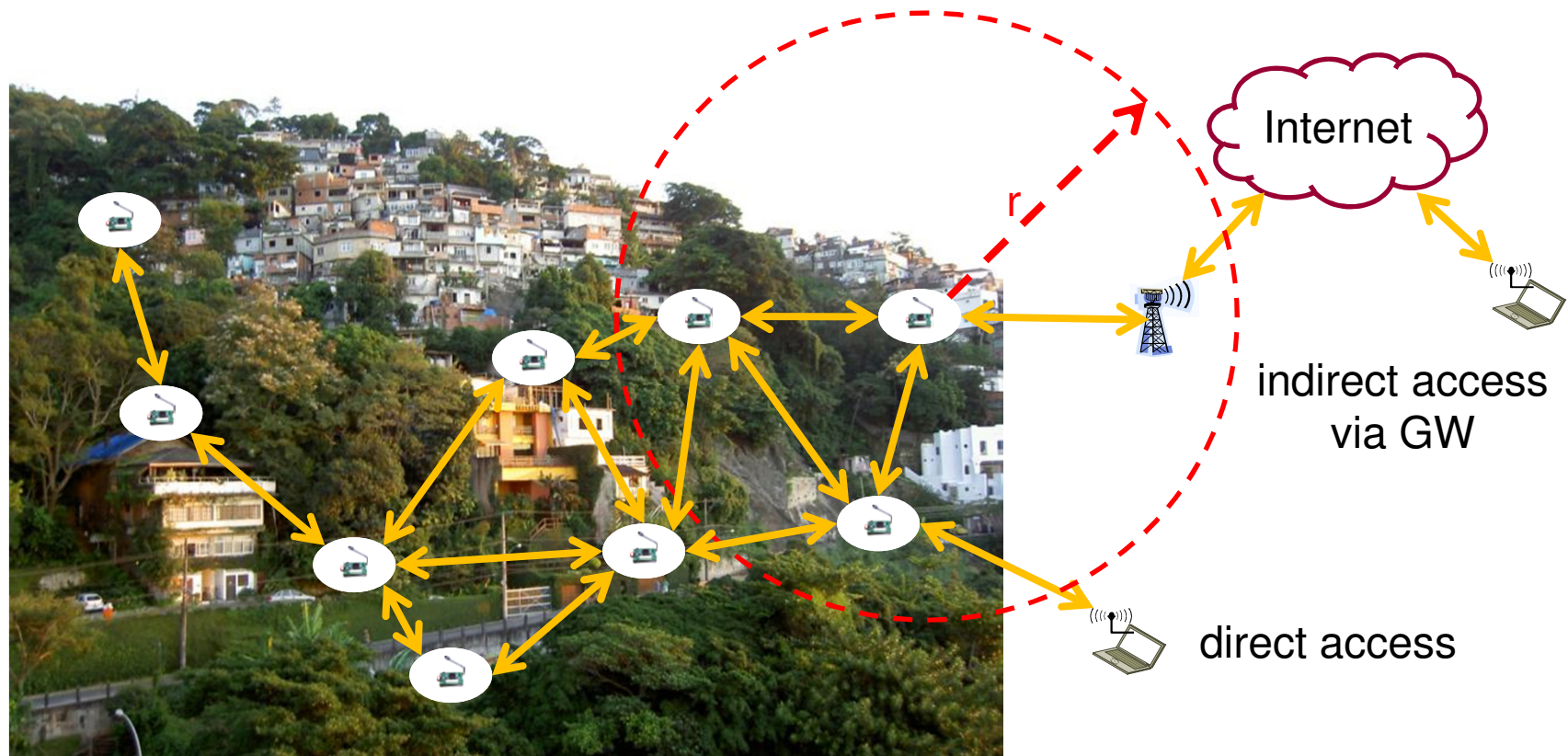

Smart Dust?

Conventional Sensor Networks

- Wireless Sensor Network (WSN)
  - Hundreds of networked sensor nodes, composed of sensors + processing/storage + wireless comm. + battery

Internet

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indirect access via GW

direct access

Applicability in Challenging Environments

- Automated observation of locations, flight trajectories, and contacts between individual bats
  - Scalability of the observations in time and space
  - Sensor platform that can be carried by a bat
- Ambitious and extremely challenging DFG research project with six partners from complementing disciplines

Mobile Sensor Node

Stationary sensor network

Management and data processing
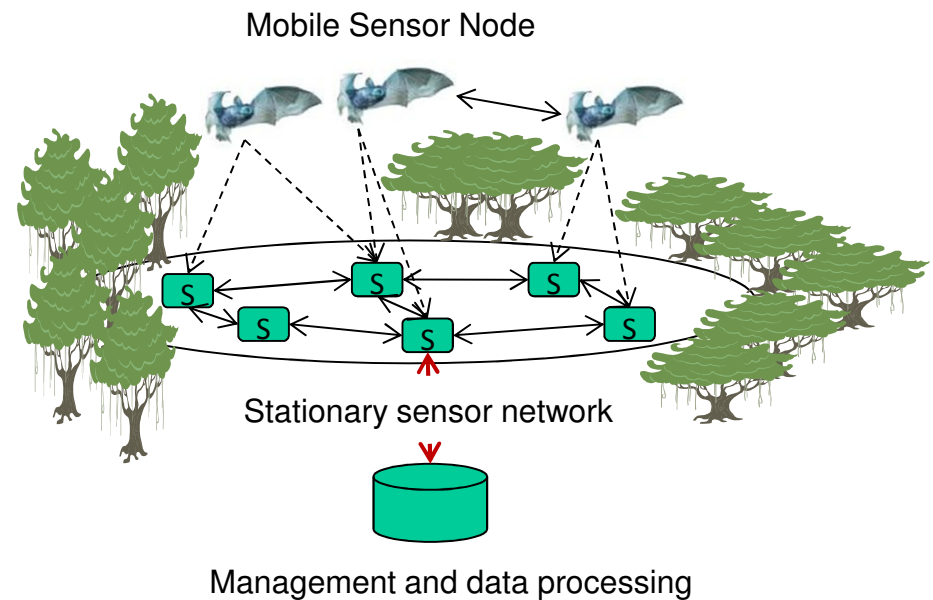
Localization of Individuals

● Radio telemetry

➡ Needs many volunteers…

local

➡ Poor localization quality in time and space

● ARGOS – satellite telemetry

➡ Unacceptable system weight

global

Quelle:
www.argos-system.org

➡ Works world wide and for long observation tasks

➡ Better localization granularity in time and space

▪ **BATS: adaptive sensor tracking systems**

» Very high localization quality
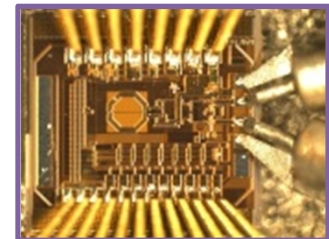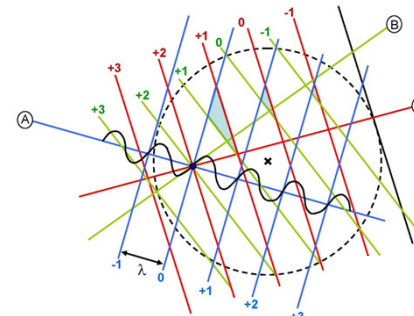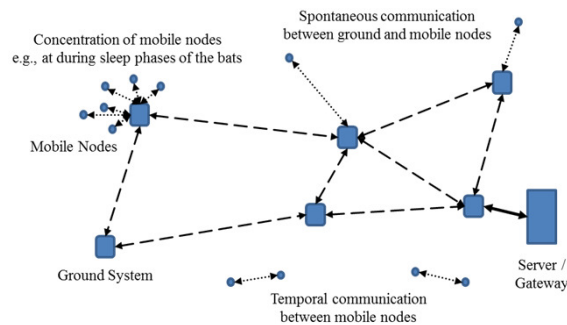» Continuous contact information

Challenging Issues

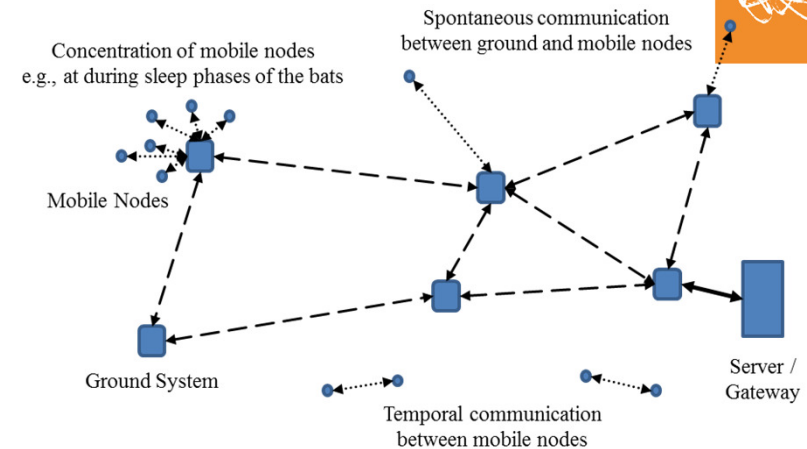🔴 Size of the sensor nodes

➡️ 2g, 1-2mm^2, lifetime up to 2 weeks

🔴 Short contact times

➡️ Less than 10 ms, less than 10 byte payload per contact

🔴 Scalability in space

➡️ Coverage, i.e., minimizing the number of necessary base stations

Challenges and Objectives

- Data communication between the bats and the stationary network
    - Multi-stage wake-up transceiver
    - Periodic "hellos" to recognize contacts
    - Use of erasure codes for data delivery

Concentration of mobile nodes e.g., at during sleep phases of the bats

Spontaneous communication between ground and mobile nodes

Mobile Nodes

Ground System

Server / Gateway

Temporal communication between mobile nodes

- Data management in the stationary network
    - Use of virtual coordinate based routing mechanisms, e.g., the Virtual Cord Protocol
    - DHT-based data management and data replication
    - Temporal data storage and identification of dynamically generated information

Virtual Coordinate based Routing
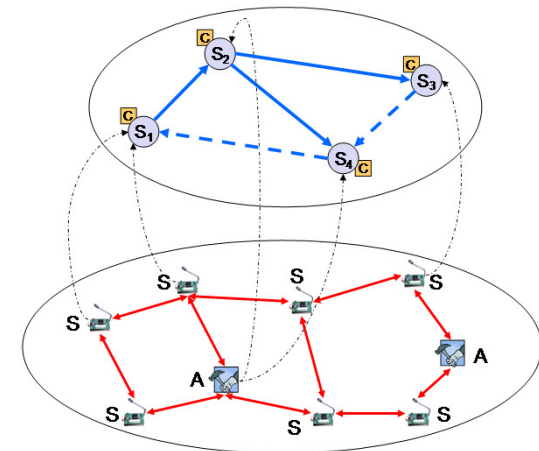
- **Virtual Cord Protocol (VCP)** [IEEE Trans on Mobile Computing 2011]
  - Greedy forwarding along the cord
    - Always guarantees reachability for any destination
  - Speedup by exploiting local short-cuts
  - Integrated data management using a distributed hash table (DHT)
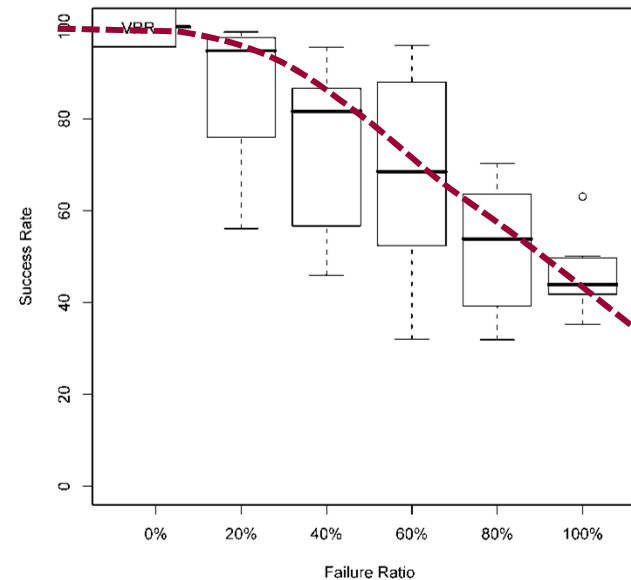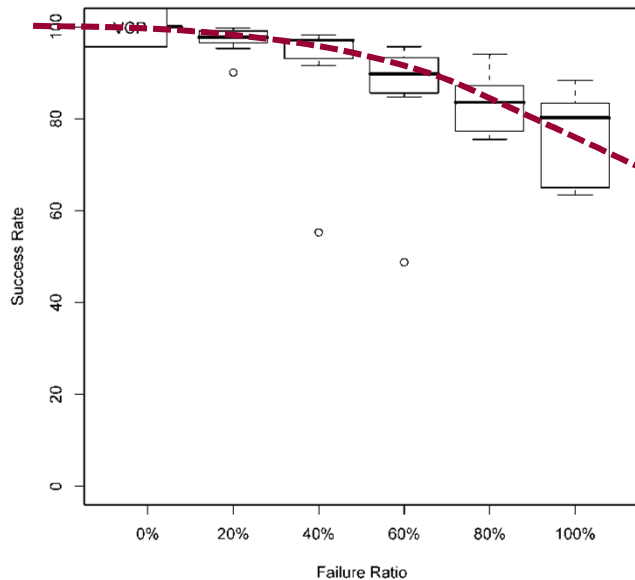
Conclusion

- The basis for IoT: Adaptive Wireless Networks!
  - From our daily use of **WiFi or Bluetooth**
  - To **industrial** real-time networks
  - To energy-constrained **sensor** networks
  - To highly dynamic **mobile** networks

- **From Hype to Reality?**
  - We need energy efficiency, robustness, security, dynamics, latency, throughput, … at the same time

- Did we get it? Not really… **but we are getting closer!**