Wireless Sensor Networks

25th Lecture

07.02.2007

CoNe Freiburg

University of Freiburg
Computer Networks and Telematics
Prof. Christian Schindelhauer

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Final Meeting
(before the exams)

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- **Meeting Point: Waldkirch, main station**
- **Date: Tuesday 27.02.2006 14:01**
  (Train departs Freiburg main station at 13:40)

- **Plan**
  - Hike the Kastelburg
  - Picknick
- **BYOF**
  - Order drinks on-line
- Don‘t forget:
  - Food
  - Umbrella
  - Matches

Data-centric and content-based networking

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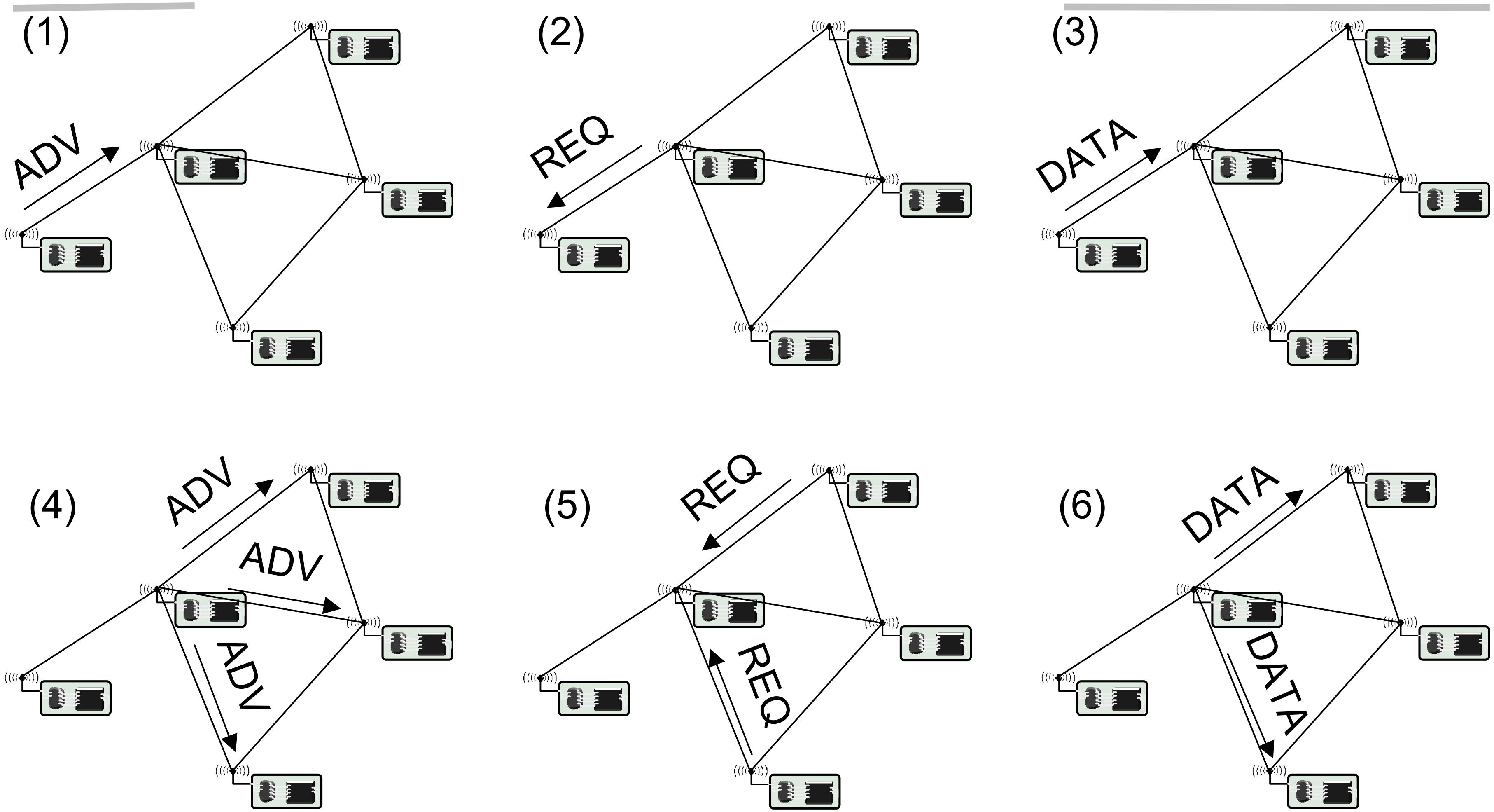
- **Interaction patterns and programming model**
- *Data-centric routing*
- **Data aggregation**
- **Data storage**

One-shot interactions with big data sets

- **Scenario**
  - Large amount of data are to be communicated – e.g., video picture
  - Can be succinctly summarized/described
- **Idea: Only exchange characterization with neighbor, ask whether it is interested in data**
  - Only transmit data when explicitly requested
  - Nodes should know about interests of further away nodes

→ *Sensor Protocol for Information via Negotiation* **(SPIN)**

SPIN example



Repeated interactions

- **More interesting: Subscribe once, events happen multiple times**
  - Exploring the network topology might actually pay off
  - But: unknown which node can provide data, multiple nodes might ask for data

  → How to map this onto a “routing” problem?
- **Idea: Put enough information into the network so that publications and subscriptions can be mapped onto each other**
  - But try to avoid using unique identifiers: might not be available, might require too big a state size in intermediate nodes

→ *Directed diffusion* **as one option for implementation**
  - Try to rely only on ***local interactions*** for implementation

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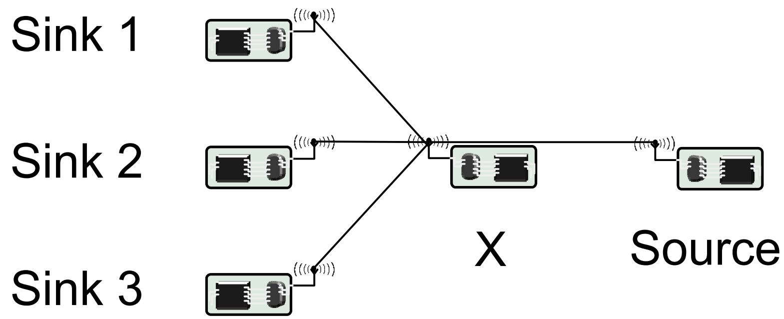
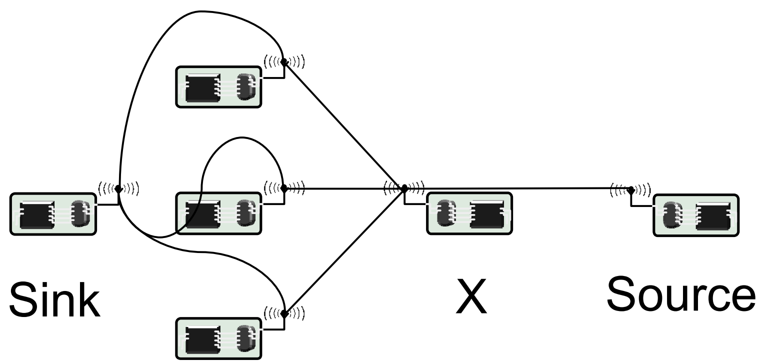
Directed diffusion – Two-phase pull

- Phase 1**: nodes distribute *interests* in certain kinds of named data**
  - Specified as attribute-value pairs (cp. Chapter 7)
- **Interests are flooded in the network**
  - Apparently obvious solution: remember from where interests came, set up a convergecast tree
  - Problem:
    - Node X cannot distinguish, in absence of unique identifiers, between the two situations on the right
    - set up only one or three convergecast trees?





Direction diffusion – Gradients in two-phase pull

- **Option 1: Node X forwarding received data to all "parents" in a "convergecast tree"**
  - Not attractive, many needless packet repetitions over multiple routes
- **Option 2: node X only forwards to one parent**
  - Not acceptable, data sinks might miss events

- **Option 3: Only provisionally send data to all parents, but ask data sinks to help in selecting which paths are redundant, which are needed**
  - Information from where an interest came is called ***gradient***
  - Forward all published data along all existing gradients

Gradient reinforcement

- **Gradients express not only a link in a tree, but a quantified "strength" of relationship**
  - Initialized to low values
  - Strength represents also rate with which data is to be sent
- **Intermediate nodes forward on all gradients**
  - Can use a data cache to suppress needless duplicates
- Second phase**: Nodes that contribute new data (not found in cache) should be encouraged to send more data**
  - Sending rate is increased, the gradient is ***reinforced***
  - Gradient reinforcement can start from the sink
  - If requested rate is higher than available rate, gradient reinforcement propagates towards original data sources
- **Adapts to changes in data sources, topology, sinks**

Directed diffusion – extensions

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- **Two-phase pull suffers from interest flooding problems**
  - Can be ameliorated by combining with topology control, in particular, passive clustering
- **Geographic scoping & directed diffusion**
- **Push diffusion – few senders, many receivers**
  - Same interface/naming concept, but different routing protocol
  - Here: do not flood interests, but flood the (relatively few) data
  - Interested nodes will start reinforcing the gradients
- **Pull diffusion – many senders, few receivers**
  - Still flood interest messages, but directly set up a real tree

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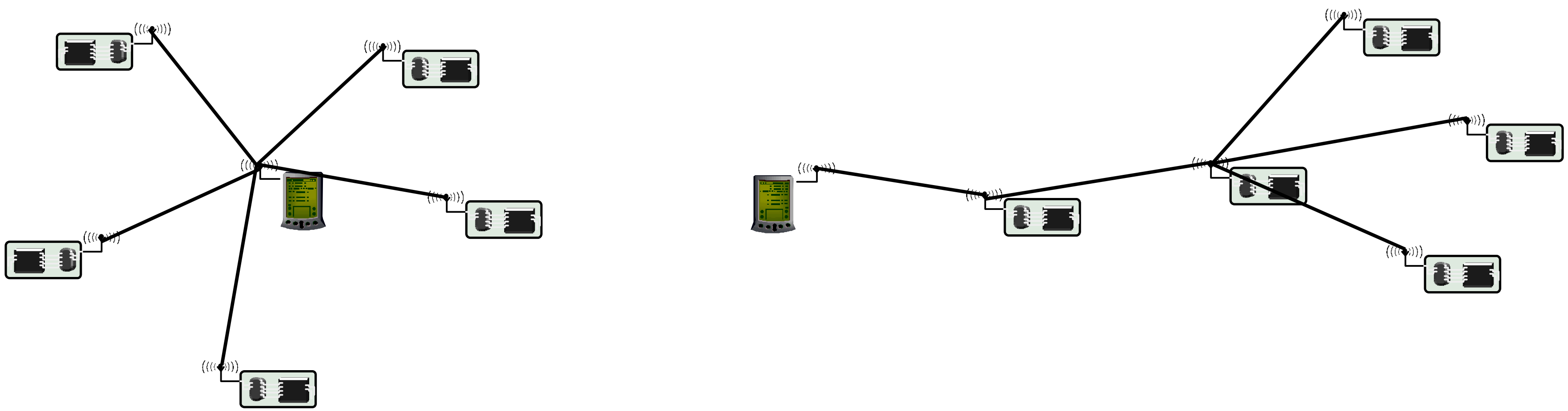
- **Interaction patterns and programming model**
- **Data-centric routing**
- *Data aggregation*
- **Data storage**

Data aggregation

- **Any packet not transmitted does not need energy**
- **To still transmit data, packets need to combine their data into fewer packets → *aggregation* is needed**
- **Depending on network, aggregation can be useful or pointless**



Metrics for data aggregation

- *Accuracy*: **Difference between value(s) the sink obtains from aggregated packets and from the actual value (obtained in case no aggregation/no faults occur)**

- *Completeness*: **Percentage of all readings included in computing the final aggregate at the sink**

- *Latency*

- *Message overhead*

How to express aggregation request?

- **One option: Use database abstraction of WSN**
- **Aggregation is requested by appropriate SQL clauses**

```
SELECT {agg(expr), attributes} FROM sensors
WHERE {selectionPredicates}
GROUP BY {attributes}
HAVING {havingPredicates}
EPOCH DURATION i
```

  – WHERE: filter on value before entering aggregation process
    - Usually evaluated locally on an observing node
  – GROUP BY: partition into subsets, filtered by HAVING
    - GROUP BY floor HAVING floor > 5

Partial state records

- **Partial state records to represent intermediate results**
  - E.g., to compute average, sum and number of previously aggregated values is required – expressed as <sum,count>
  - Update rule: $< s, c > = < s_1 + s_2, c_1 + c_2 >$
  - Final result is simply s/c

Aggregation operations – categories

- **Duplicate sensitive, e.g., median, sum, histograms; insensitive: maximum or minimum**
- **Summary or examplary**
- **Composable:**
  - for f aggregation function, there exist g such that
    - $f(W) = g(f(W_1), f(W_2))$ for $W = W_1 \cup W_2$
- **Behavior of partial state records**
  - Distributive – end results directly as partial state record, e.g., MIN
  - Algebraic – p.s.r. has constant size; end result easily derived
  - Content-sensitive – size and structure depend on measured values (e.g., histogram)
  - Holistic – all data need to be included, e.g., median
- **Monotonic**

Placement of aggregation points

- **Convergecast trees provide natural aggregation points**
- **But: what are *good* aggregation points?**
  - Ideally: choose tree structure such that the size of the aggregated data to be communicated is minimized
  - Figuratively: long trunks, bushy at the leaves
  - In fact: again a Steiner tree problem in disguise
- **Good aggregation tree structure can be obtained by slightly modifying Takahashi-Matsuyama heuristic**
- **Alternative: look at parent selection rule in a simple flooding-based tree construction**
  - E.g., first inviter as parent, random inviter, nearest inviter, …
  - Result: no simple rule guarantees an optimal aggregation structure
- **Can be regarded as optimization problem as well**

Alternative: broadcasting an aggregated value

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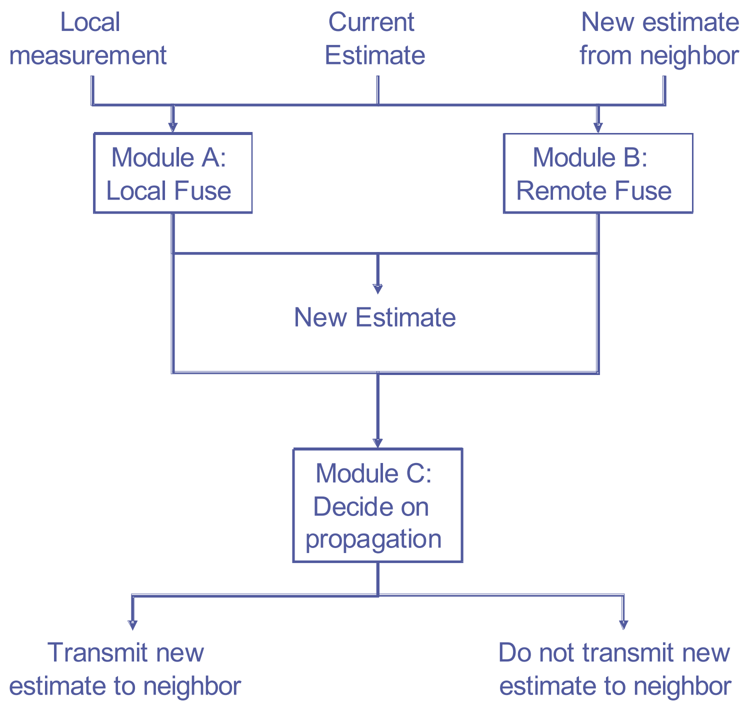
- **Goal is to distribute an aggregate of all nodes' measurements to all nodes in turn**
  - Setting up |V| convergecast trees not appropriate
- **Idea: Use gossiping combined with aggregation**
  - When new information is obtained, locally or from neighbor, compute new estimate by aggregation
  - Decide whether to gossip this new estimate, detect whether a change is "significant"



Thank you

and thanks to Holger Karl for the slides

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