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Too Wired?

I just tried to email you & it bounced back. Try IMing me.

MAKING LUNCH PLANS IN THE 21st CENTURY
Wireless Sensor Networks

“accurate and energy-efficient sensing is critical”

dormant state

WINLAB Research Review, May 2006
Congestion Controls

- Why congestion?
  - Traffic > Resource

- Desired State
  - Traffic <= Resource
Why Resource Control?

- **MUST**
  - Needs to meet application’s fidelity requirement
    - data during congestion is of utmost importance (e.g. report of fire).
    - source quenching by traffic control violates fidelity requirement.

- **CAN**
  - Exploit redundancy of resource deployment
    - quick control of elastic resources is viable in sensor networks (e.g. power control, multipath routing).

- **HOW**
Previous Work

- Traffic Control
  - Fair scheduling
    - EPS (SenSys’04)
  - In-network Aggregation (or Compression)
    - TAG (OSDI’02)
  - Hop-by-hop & end-to-end control
    - CODA (SenSys’03), ESRT (MobiHoc’03), Adaptive Rate Control (MobiCom’01)
    - spatial spreading (Infocom’04)
  - Prioritized MAC
    - Fusion (SenSys’04)

- Resource Control
  - Routing
    - load-aware routing (ICC’01)
    - congestion-adaptive routing (WCNC’05)
  - Power Control
    - JOCP (Infocom’04)
Traffic Control vs Resource Control

- **Traffic Control**
  - utilization and fairness
  - fixed resource
  - Additive Increase/Multiplicative Decrease (AIMD)
    - \( T(t+1) = \begin{cases} 
    T(t) + a & \text{if } T(t) < R \\
    mT(t) & \text{if } T(t) > R 
    \end{cases} \)
  - decrease operation when congested

- **Resource Control**
  - fidelity and energy
  - variable resource
  - no fairness
  - increase operation when congested
Goals

- Policy
  - Try to understand the ideal behavior of resource control

- Mechanism
  - Use the understanding to implement a resource control scheme in sensor networks.

- Challenges

  “Traditional traffic control frameworks are not applicable”
Early Increase/Early Decrease Policy

- **Metrics**
  \[
  \frac{\text{Total Energy Consumption}}{\text{Fidelity}^{\text{obs}}} = \text{Energy Efficiency}
  \]

- **Objective**
  - minimize Energy Efficiency while \(Fidelity^{\text{obs}} > Fidelity^{\text{req}}\)

- **Trinary feedback**
  - if above upper watermark, \(R(t+1) = T(t) + \alpha\)
  - if inside watermarks, \(R(t+1) = R(t)\)
  - if below lower watermark, \(R(t+1) = T(t) + \alpha\)

- **Optimal at end-to-end level**

- **Traffic Volume or Resource Capacity**

  - packet drops (fidelity degradation)
  - idle capacity (energy waste)

- **Time**

  - event detection
  - congestion alleviation

**Symbols**

- \(R\): available resource
- \(H_b\): bottleneck area

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Focus of Research

- **Policy**
  - Early Increase/Early Decrease (EIED)

- **Mechanism**
  - routing topology change (TARA)

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If we need 37.5% more bandwidth, how many additional nodes need to be turned on and in what topology?

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Lazy Measurement [WCNC'05]

congestion measurement → congestion notification → fidelity met? → traffic control

resource control

required resource (capacity) → topology change
Capacity Analysis Model

- **Definition**
  - \( T \): one unit of traffic
  - 1 time frame: time interval for a node to transmit one unit of traffic to its immediate neighbor, i.e. one hop.

- **Capacity estimation**
  - capacity fraction: \# of traffic units / required time frames
  - estimated capacity = capacity fraction * maximum one-hop capacity (\( C_{\text{max}} \))
Lesson: The capacity of a merging topology can be increased by moving the merging point within a small number of hops from the sink.
The real egoistic behavior is to cooperate.

- K. Edwin
Topography-Aware Resource Adaptation (TARA)

- stream-based vs. flow-based
  - a stream: all incoming flows destined for the same sink
- hotspot vs. intersection zone
- 5 steps
  - Detecting congestion
  - Finding the distributor
  - Finding the merger
  - Creating the detour path
  - Distributing the incoming traffic
Detour Path Discovery

- **Goal:**
  - To minimize the number of local rebroadcasts

- **Reducing rebroadcast**
  - local flooding
  - self-pruning by hop count based rebroadcast

- **Reliability**
  - Random Access Delay (RAD)
  - Unsuccessful reception due to collision with data packets: mostly near the congested nodes

- **Prevent parallel resource controlling**
  - Overhearing the upstream control message
  - Congestion bit in the packet header
Merger Selection & Traffic Distribution

- **Congestion scenarios**
  - 3 sharing types
    - no sharing, node sharing, link sharing
  - 4 hotspot building blocks for two dominant streams
  - 3 intersection zones
    - braided, crossing, merging

- **Merger selection**
  - braided or crossing intersection zones
    - non-congested downstream node
  - merging intersection zone
    - based on distance to sink

- **Traffic distribution**
  - weighted fair-share scheduling
  - inversely proportional to congestion level
  - \( \frac{T_{\text{original}}}{T_{\text{detour}}} = \frac{C_{\text{detour}}}{C_{\text{original}}} \)
Simulation Environment

**sensor field**
- 81 nodes in 160x160m
- 802.11 DCF 2M bps
- no RTS/CTS
- radio: 30m(T), 50m(I)

**traffic model**
- event duration: 10 sec
- peak rates: 33.3~66.9 packets/sec/source
- packet size: 100 bytes
- energy consumption: 13.5(I), 13.5(R), 24.75mW(T)
Simulation Strategies

- Strategies
  - no congestion control
    - a baseline scenario
  - traffic control
    - back-pressure message to the upstream nodes.
  - topology-unaware resource control
    - chooses the first downstream node with a low congestion level as a merger to form the detour path.
    - blindly routes all the packets to the detour path.
  - TARA
  - ideal resource control
    - optimal offline resource control algorithm.
    - finds an optimal topology.
    - cannot be implemented in a real system.
Congestion Control Scenarios

- no congestion control
- topology-unaware rc
- ideal rc TARA
Fidelity Index

Fidelity index observed at sink (merging topology)

- ideal rc
- no congestion control
- traffic control
- topology-unaware rc
- TARA

peak reporting rate per source (in packets/sec)
Total Energy Consumption

Energy consumed by network during event period (merging topology)

- ideal rc
- no congestion control
- traffic control
- topology-unaware rc
- TARA

Total energy consumption (in Joule)

peak reporting rate per source (in packets/sec)

Topography-unaware R.C.

TARA

Traffic Control
Bit Energy Consumption

Energy consumed by network per delivered bit (merging topology)

bit energy consumption (in micro Jou) vs peak reporting rate per source (in packets/sec)

Ideal rc
No congestion control
Traffic control
Topology-unaware rc
TARA

Resource control overhead

Topology-unaware R.C.
Traffic Control
TARA
Conclusion

- A new approach to control congestion in sensor networks based on resource control.

- Fidelity-met, energy-efficient, and distributed.

- The data delivery and energy conservation of TARA is very close to the ideal case.
Future Work

- Unified congestion control framework
  - Traffic control + Resource control
  - Resource control using various resource control means (e.g. power)

- Coping with transient congestion.

- Quick decision about resource availability.
Thank you!

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Project Home:
http://paul.rutgers.edu/~jwkang/research/tara.html

• As of May 2006, I am looking for a full-time research position. Please, feel free to contact me for any questions.