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An Adaptive Epidemic Information Dissemination Scheme with Cross-layer Enhancements

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Outline

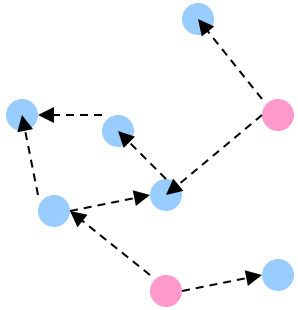
- Rationale
- System & Channel Model
- Adaptive Dissemination Scheme
- Performance Metrics & Results
- Future Work

Rationale

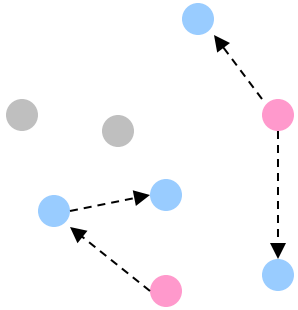
- Epidemics in data dissemination: a **probabilistic** scheme for information spreading in Ad-Hoc Networks
  - *Transmit data to interested (susceptible) neighbors in a probabilistic rather than flooding manner*
  - Reduces redundant communication due to its probabilistic nature
- **Adaptive** Dissemination:
  - offers additional reduction thanks to *adaptive modulation & coding* (AMC) and rationalised resource utilisation

Rationale

An Effectiveness – Efficiency *trade-off*



High coverage
High energy cost



Low coverage
Low energy cost

System Model

- Channel Model
  - Noisy wireless channel (AWGN)
  - Error correction (convolutional)
  - Multi-hop, multipath propagation
- Network Model & Adaptive Epidemic Scheme
  - Finite RF range –> each node's neighborhood
  - **Forward** infecting data with probability β
  - **Adjust** β based on local information
  - **Switch** code rate and modulation scheme (AMC) based on local SNR perception

Channel Model

Adoption of the model [1] offering channel noise awareness

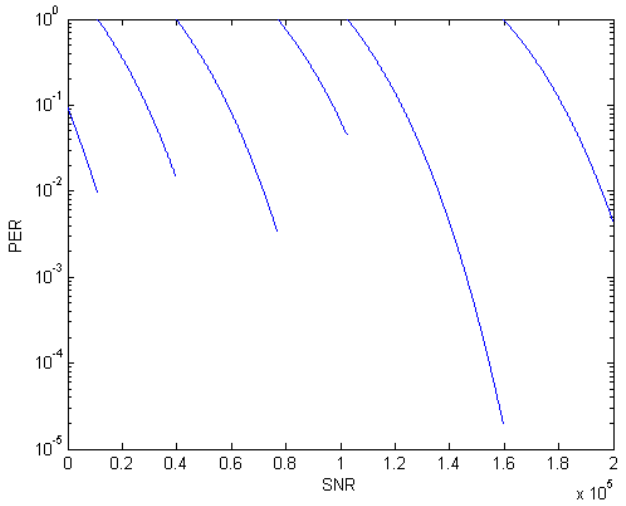
- Use AMC
- Different Modulation & Convolutional Encoding acc. to SNR
- PER calculated accordingly:

$$PER = \begin{cases} a_n \exp\left(-g_n \gamma\right) \text{if } \gamma \geq \gamma_{pn} \\ 1, \text{ otherwise} \end{cases}$$

[1] Qingwen Liu, Shengli Zhou, & Georgios B. Giannakis, "Cross-Layer Combining of Adaptive Modulation and Coding with Truncated ARQ over Wireless links“ IEEE Trans. Wireless Comm. 3(5): 1746-1755, Sept. 2004

Channel Model

	MODE 1	MODE 2	MODE 3	MODE 4	MODE 5	MODE 6
Modulation	BPSK	QPSK	QPSK	16-QAM	16-QAM	64-QAM
Coding Rate	1/2	1/2	3/4	9/16	3/4	3/4
Rate (bps)	0.50	1.00	1.50	2.25	3.00	4.50
α_n	274.7229	90.2514	67.6181	50.1222	53.3987	35.3508
g_n	7.9932	3.4998	1.6883	0.6644	0.3756	0.0900
$\gamma_{pn}(dB)$	-1.5331	1.0942	3.9722	7.7021	10.2488	15.9784



from: Qingwen Liu, Shengli Zhou, & Georgios B. Giannakis,
"Cross-Layer Combining of Adaptive Modulation and Coding With Truncated ARQ Over Wireless links"

Adaptive Dissemination Scheme

- Start with a few infected nodes
- Infected nodes:
  - May be cured (probability δ)
  - May try to infect others (forwarding probability β)
  - May receive *infecting* messages (i.e. duplicate message rate)
  - May receive *corrupt* infecting messages (check first!)

  Always possible that you try to infect an already infected node!
- Susceptible nodes:
  - May receive infecting messages
  - May receive *corrupt* infecting messages (i.e. error rate)

  The wireless channel is not always friendly!

Adaptive Dissemination Scheme

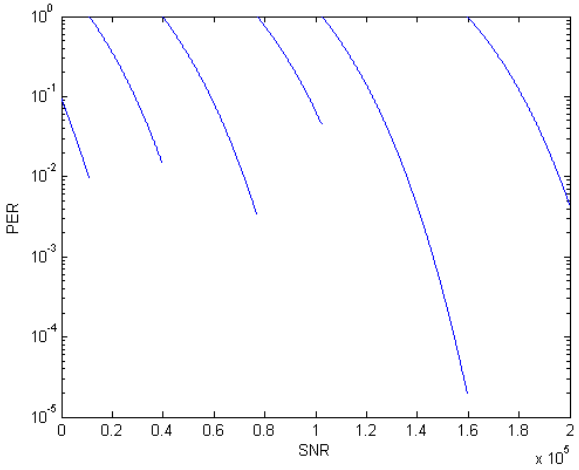
- Measure **error rate** and **duplicates rate** locally
  - High error rate $e_i(t)$ means we need to shout louder to be heard!
  - High duplicates rate $d_i(t)$ means the opposite!
- Two alternative adaptation equations:

$$\beta(t+1) = \beta_0\left(1 - \kappa_1 d_i(t) + \kappa_2 e_i(t)\right) \qquad \beta(t+1) = \frac{\beta_0}{1 + \kappa_3 e^{1-\kappa_1 d_i(t) + \kappa_2 e_i(t)}}$$

- Use local information from receptions to adapt your transmissions!

Adaptive Dissemination Scheme

- Measure SNR (γ) and perform mode switch at SNR threshold crossings
- If $\gamma_{pn} < \gamma < \gamma_{pn+1}$ then choose mode #*n*
  - Remain at modest PER values
  - Reduce overhead in low noise environments



- Use local SNR information to adapt transmissions!

[1] Qingwen Liu, Shengli Zhou, & Georgios B. Giannakis, "Cross-Layer Combining of Adaptive Modulation and Coding with Truncated ARQ over Wireless links“ IEEE Trans. Wireless Comm. 3(5): 1746-1755, Sept. 2004

Performance Metrics

Independent Parameters

- Signal-to-Noise Ratio
- Initial forwarding rate
- Network Density
- Mobility

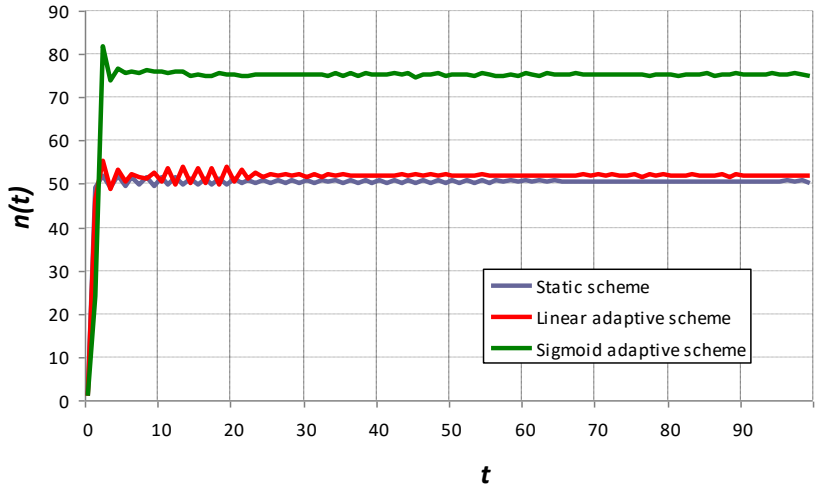
Context

- Error rate
- Duplicates rate

Metrics

- Coverage Rate
- Forwarding Prob.
- Transmission Cost
- Efficiency $a(t) = \frac{n(t)}{M(t)}$ coverage rate over transmissions count
- Energy Cost Save

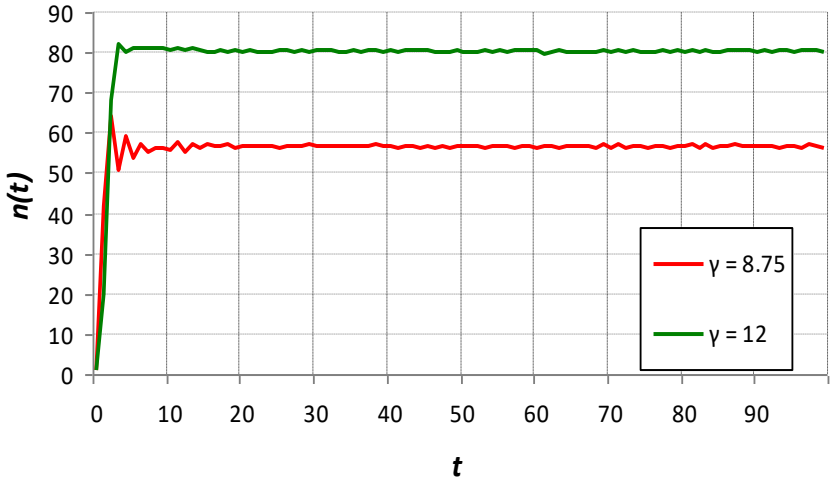
Results



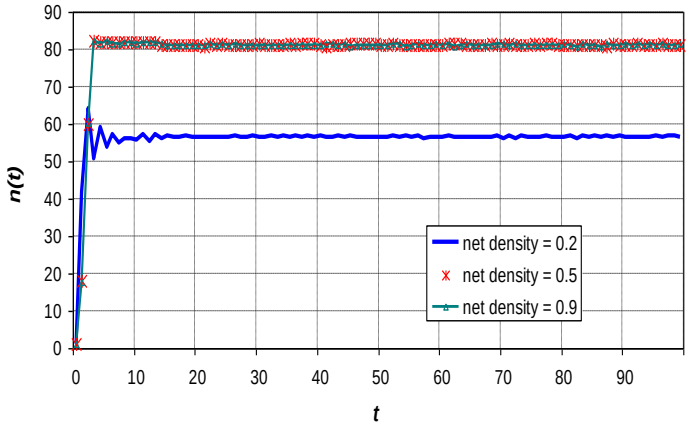
β_0=0.5, SNR=8.75 dB, ρ=0.2, σ^2/N_0=0.7

- Forwarding probability suppressed
- Coverage rate converges quickly
- … resulting in energy cost saving

Low noise is favorable; coverage rate converges…
- faster
- to higher values



Results

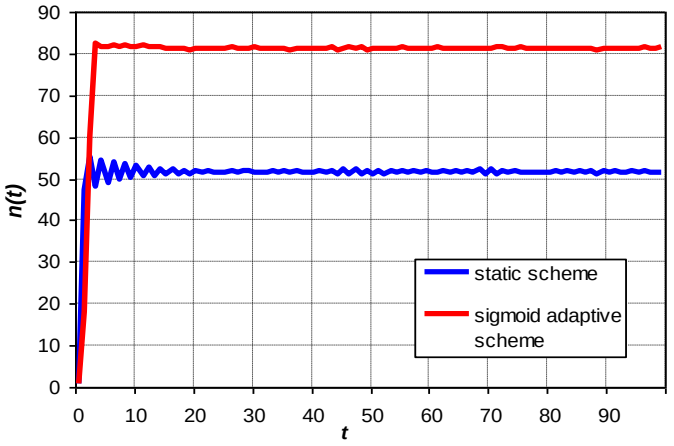


Dense networks favor dissemination…

β_0=0.5, SNR=8.75 dB, σ^2/N_0=0.7

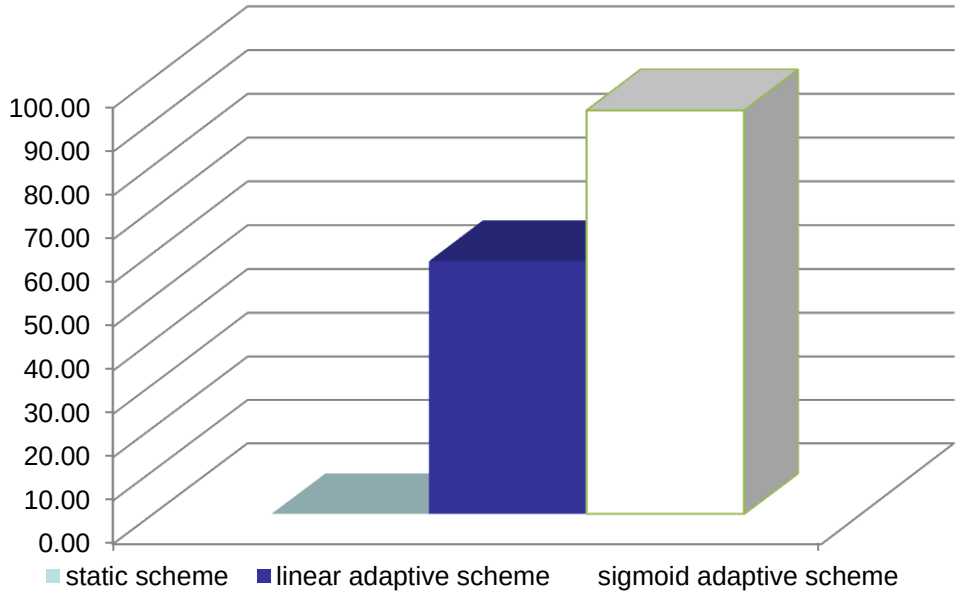
Mobile* settings display similar behavior

*Random waypoint model adopted



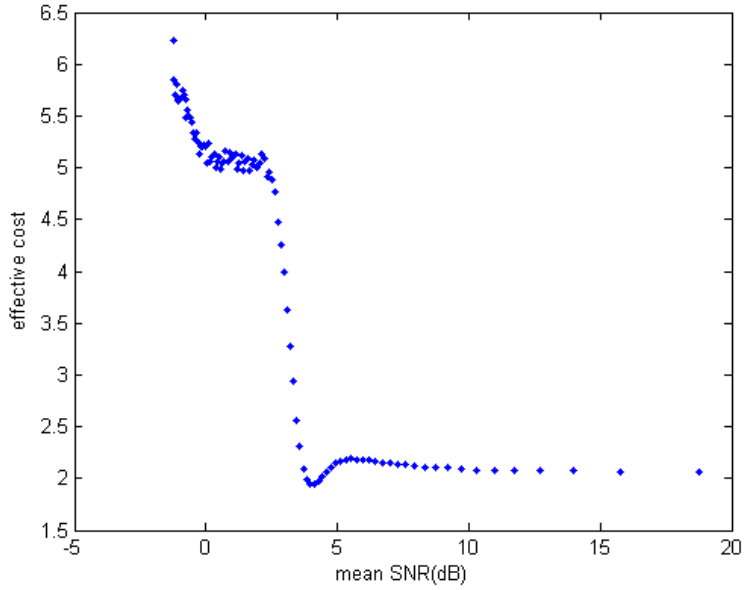
Results

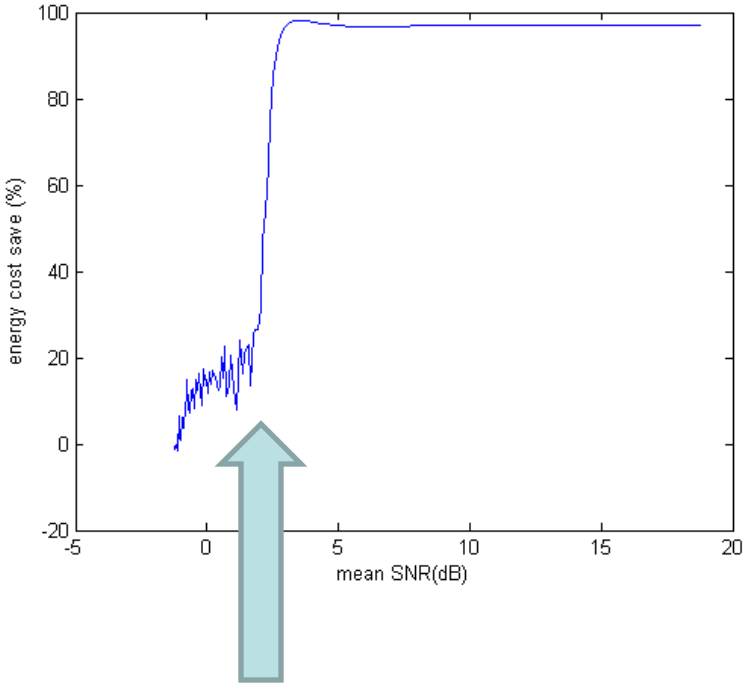
- Energy saved thanks to…
  - reduced overhead
  - regulated forwarding probability
- Good coverage thanks to avoidance of high-PER conditions



Results

Cost save





Lower limit of lowest AMC mode

Summary & Future Work

- Summary
  - Generic model (summarize adaptation methods)
  - Proof of concept for cross-layer context awareness (passive scheme avoiding polling)
- Future Work
  - **Optimum** adaptive dissemination schemes
  - Influence of the bandwidth competition on the scheme

Thank you!

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