SMACK - A SMart ACKnowledgement Scheme for Broadcast Messages in Wireless Networks

COMP635 -- Paper Presentation

Junhua Yan
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Reliable Transmission in Wireless Network

- Transmit at the lowest modulation rate \((\text{bits per symbol})\)
- Send one ACK after another

*Can we send all replies at the same time thus reducing ACK time?*

-- SMACK
OFDM

- Orthogonal channels based on Frequency Division Multiplexing (FDM)
- iFFT/FFT

\[ X(n) = \sum_{i=0}^{N-1} x(k) \sin \left( \frac{2\pi kn}{N} \right) - j \sum_{i=0}^{N-1} x(k) \cos \left( \frac{2\pi kn}{N} \right) \]

Figure 1. OFDM achieves higher spectrum efficiency\[1\]

NC-OFDM$^{[1][2]}$

- Non-contiguous blocks of subcarriers

Figure 2. Non-contiguous OFDM transmission

802.11g: 53 subcarriers

SMART Acknowledgments

1) Each client is assigned a unique “membership id”
2) AP broadcasts a message
3) Client decodes the message upon receiving the message if possible

Figure 3. Subcarrier assignment in a network
SMART Acknowledgments

4) Client uses assigned subcarrier specified by the “membership id” to send back an ACK
5) AP receives composite signal of all subcarriers and demodulates the individual’s ACK

*Question: how can AP detect when a client is transmitting a signal? -- threshold*

![Figure 4. Received Signal Strength](image-url)
Robustness of SMACK

- Varying Signal Power
- Interference
Varying Signal Power

- **Problem**: signal powers from clients may vary
- **Solution**: adjust transmission power of clients such that received power from all clients are within a tolerant range[^1]

*Question: what if protocol failed to detect weakest client’s signal?*

Interference

- **Problem**: spurious or burst noise
- **Solution**: fallback mechanism

*Figure 5. Protocol Fallback Decision Tree*
Interference (cont.)

- Assign each client *multiple subcarriers* to transmit ACKs
  - *all or nothing decision metric*

Interference < 20 MHz: Zigbee 5 MHz

False Positive
Interference (cont.)

- Keep two subcarriers unassigned to any clients
Time Considerations

- All subcarriers must be present with sufficient energy within the FFT window to extract spectral components
  - Near-far effect
  - Different processing power of clients

\[ T \geq 2 \times T_{\text{propagation}} + T_{\text{rx latency}} + T_{\text{hardware}} + T_{\text{tx latency}} \]
Experiment Setup

- SDR platform with an OFDM transceiver on a Virtex-IV FPGA
- Carrier frequency: 2.484 GHz
Variation of spectrum over time

- 192 (64×3) $FFT$ computation
- Variation of spectrum energy in both frequency and time

Fig 8. Variation of spectrum over time.
Results

● Efficiency of Subcarrier Detection Mechanism
  ○ Evenly spaced subcarriers
  ○ Closely spaced subcarriers
  ○ Contiguous spaced subcarriers

● Complete System performance
Evenly Spaced Subcarriers

(a). Detection percentage

(b). False positive and false negative

[-26, -16, -6, +6, +11, +16]
Closely Spaced Subcarriers

(a). Detection percentage

(b). False positive and false negative
Contiguous Subcarriers

(a). Detection percentage

(b). False positive and false negative
Results

- Efficiency of Subcarrier Detection Mechanism
- Complete System performance
  - $[-12, +12]$
Limitation

- Lack of detailed explanation about experimental results

Why percentage of False Positive decreased as we move subcarriers closer?
Open Issues

- Mobility
- Reduce Redundant Rebroadcast
- Parallel Polling
Mobility

- Frequency offset and doppler shift
- *Potential issue:* maintain a valid map from each client to ‘membership id’ in a highly dynamic topology
Reduce Redundant Broadcast

- **Problem**: Broadcast Storm in Multihop wireless networks
- **Solution**: determine farthest node for next broadcast
- **Potential issue**: should encode direction information together with the distance information
Parallel Polling

- Assign variable slots to each client based on queue length
- *Potential issue*:
  - Strict time synchronization\(^1\) required if it is not a simple ‘yes/no’ question

Thanks!

All figures used in this presentation are credited to “SMACK: A SMart ACKnowledge Scheme for Broadcast Messages in Wireless Networks” paper and presentation in not specific
Time Considerations (cont.)

- $T_{\text{hardware}}$: time for a co-sender to switch from reception to transmission
- $T_{\text{rxlatency}}$: arrival of the first sample of the packet at a node and the instant at which the receiver detects the packet
- $T_{\text{txlatency}}$
- $T_{\text{propagation}}$: time of flight of the signal between nodes
Complete System Performance

- Subcarriers: [-12, +12]

FP: 2.5%