Error Control Strategies for WiMAX Multi-Hop Relay Networks

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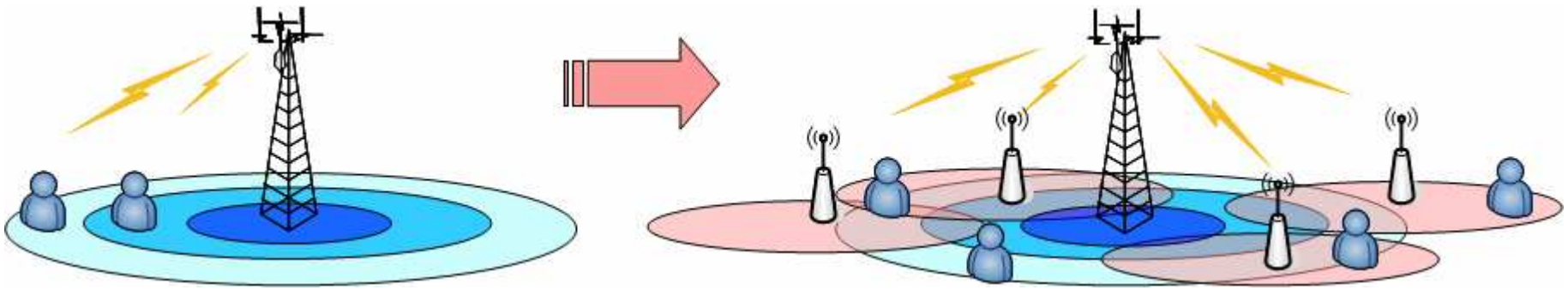
Outlines

- Introduction
- Related Works
- Error Control Analysis
- Performance Evaluations
- Conclusions

Introduction

- Both advanced WiMAX (802.16m) and LTE (LTE-A) have adapted multi-hop relay architecture for
  - Throughput enhancement
  - Coverage extension
- However, throughput degrades as the number of hops increases
  - Even in an error-free multi-hop environment
- For meet the performance and reliability requirements of 4G, an efficient error control mechanism is desired
  - Relay ARQ and HARQ

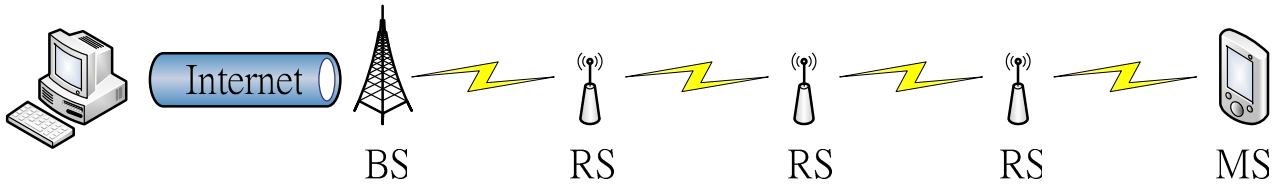


Introduction

- The factors dominating the performance
  - Buffer size
  - Propagation delay
  - Transmission error probability
  - Acknowledgement feedback

- Different values of the factors lead to completely different conclusions
  - Link-by-link approach is better since it can retransmit packet as soon as possible
  - End-to-end approach is better if feedback delay is considered

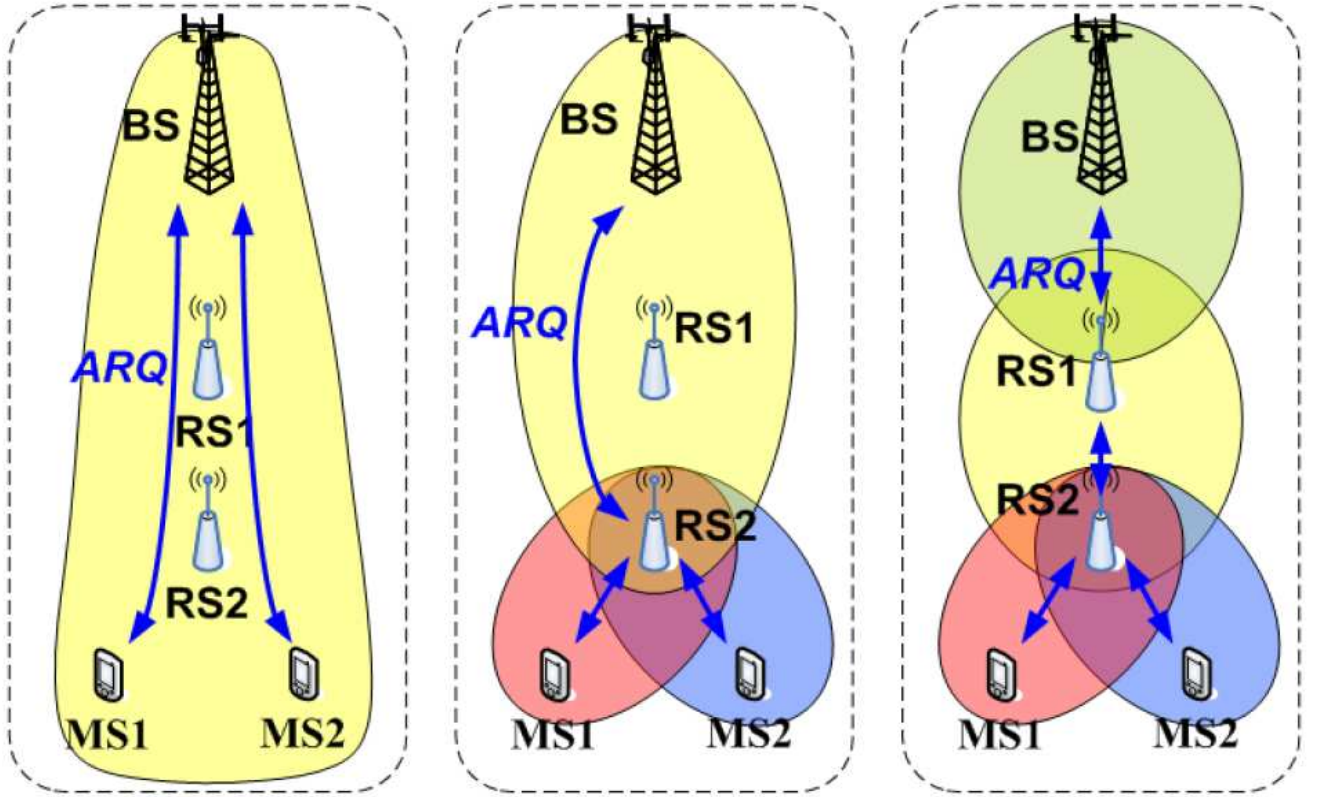
- This paper provides
  - The investigation of error control protocols and the combinations
  - A low complexity error control mechanism for multi-hop relay transmission



Related Works

- Basically, there are three relay ARQs
  - End-to-End ARQ
    - ARQ is performed between BS and MS
  - 2-Link ARQ
    - In first link, ARQ is performed between BS and the last hop RS
    - In second link, ARQ is performed between the last hop RS and MS
  - Hop-by-Hop ARQ
    - ARQ is initiated for each hop

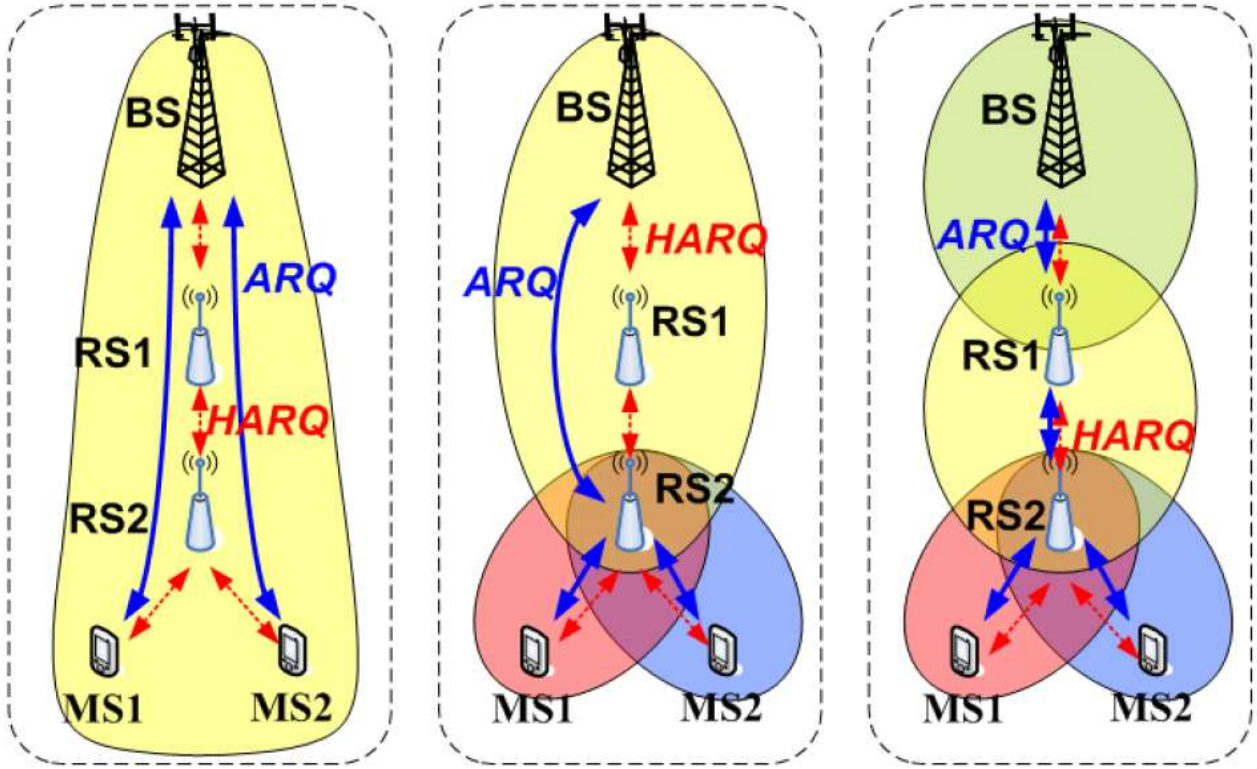
Related Works



Related Works

- The combination of ARQ and HARQ
  - End-to-End ARQ with HARQ
    - Per-hop HARQ under End-to-End ARQ
  - 2-Link ARQ with HARQ
    - Per-hop HARQ under 2-Link ARQ
  - Hop-by-Hop ARQ with HARQ
    - ARQ and HARQ are used for every hop
    - Most complicated
      - Every RS has to build state machine and allocate resource for HARQ
      - Large amount of HARQ state machine has to be collected from all RSs during handover

Related Works

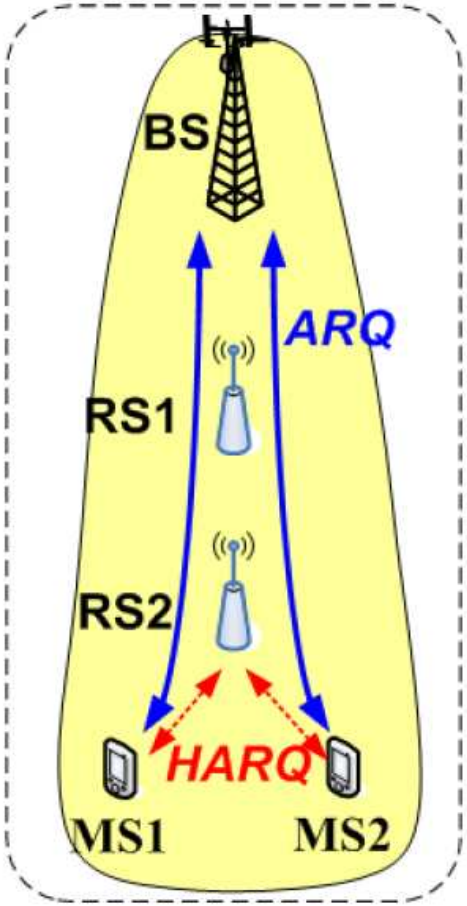


Related Works

- Observations
  - Relay link (BS⇔RS) has much lower block error rate (BLER) as compared to that of access link (RS⇔MS)
    - RSs are usually stationary and the location is pre-determined
      - Per-Hop HARQ is not necessary for relay links
    - MS may have various mobility
      - Higher BLER in access link
      - The usage of HARQ helps in access link

Proposal

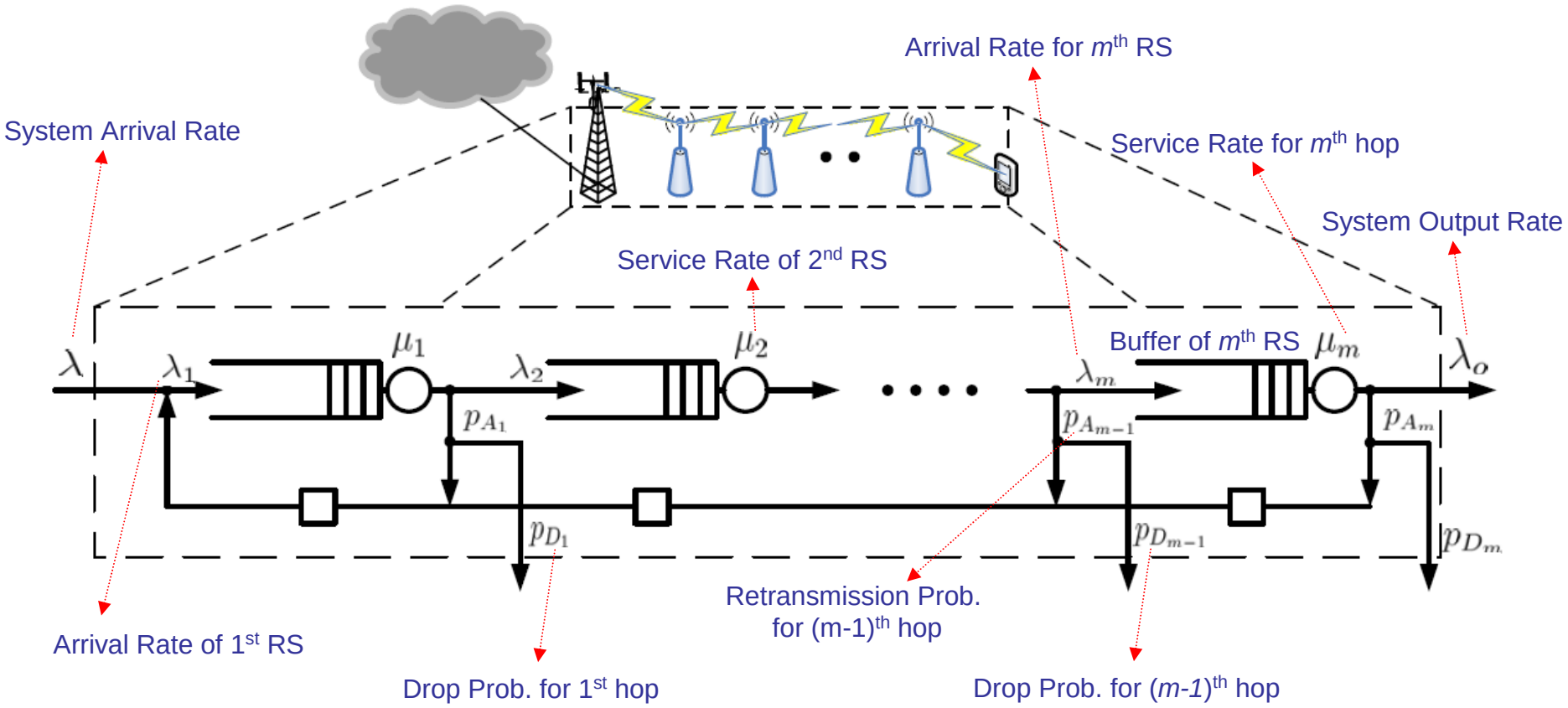
- HARQ only applies in access link
  - Less state machine used and exchanged
- ARQ is between BS and MS for End-to-End error control
  - Relay link can be optimized in implementation
  - BLER is usually low



(g) Two-link-ARQ -HARQ

Error Control Analysis

- Multi-Hop Error Control



Error Control Analysis

- Arrival rate at each queue

Arrival Rate Outside

Transition Prob.

$$\lambda_i = \lambda_{0i} + \sum_{j=1}^{m} \lambda_j p_{ji},$$

- Arrival rate at the first node
  - System arrival + retransmissions

$$\lambda_1 = \lambda + \sum_{j=1}^{m} \lambda_j p_{A_j}(1 - p_{D_j}).$$

- Arrival rate at *i*th hop node

$$\lambda_i = \frac{\lambda P_l^{(i-1)}}{1 - \sum_{j=1}^{m} p_{A_j}(1 - p_{D_j}) P_l^{(j-1)}}$$

- Visiting rate at *i*th hop node
  - ARQ burst visiting the *i*th hop node

$$e_i = \frac{P_l^{(i-1)}}{1 - \sum_{j=1}^{m} p_{A_j}(1 - p_{D_j}) P_l^{(j-1)}}$$

Error Control Analysis

- Mean response time

Service Time

Transmission Time

$$\overline{T}_Q(i) = \frac{E[n_i]}{\lambda_i} + T_c(i)$$

- Acknowledge Time (From destination to source)

Propagation Delay

Receiving burst and sending the ACK

$$T_{ACK} = \sum_{i=1}^{m} \frac{1}{\mu_i} + mT_p + T_A$$

- Average delay for ARQ transmission

$$\overline{T}(m, \mathbf{p}_A) = \sum_{i=1}^{m} e_i \overline{T}_Q(i) + (e_1 - 1)T_{ACK}$$

Error Control Analysis

- Given *h* hops links from BS to MS, the average delay for ARQ transmission is:

$$\overline{D}(h) = \begin{cases} \sum_{i=1}^{h} \overline{T}(1, p_{a_i}), & \text{hop-by-hop} \\ \overline{T}(h-1, \mathbf{p}_a^{h-1}) + \overline{T}(1, p_{a_h}), & \text{2-link} \\ \overline{T}(h, \mathbf{p}_a), & \text{end-to-end,} \end{cases}$$

$P_a = \{P_{a1}, \ldots P_{ah}\}$ as the prob. vector of burst error on total *h* hop links

Error Control Analysis

- The connection delay for various ARQ with HARQ is

$$\overline{D}_H(h) = \begin{cases} \sum_{i=1}^{h} \overline{T}_H(1, p_{r_i}), & \text{hop-by-hop} \\ \overline{T}_H(h-1, \mathbf{p}_r^{h-1}) + \overline{T}_H(1, p_{r_h}), & \text{2-link} \\ \overline{T}_H(h, \mathbf{p}_r), & \text{end-to-end.} \end{cases}$$

Response Time

$$\overline{T}_Q^H(i) = \frac{E[n_i]}{\lambda_i} + T_c^H(i)$$

Acknowledge Time

$$T_{ACK}^H = \sum_{i=1}^{m} \frac{1}{\mu_i^H} + mT_p + T_H$$

Error Control Analysis

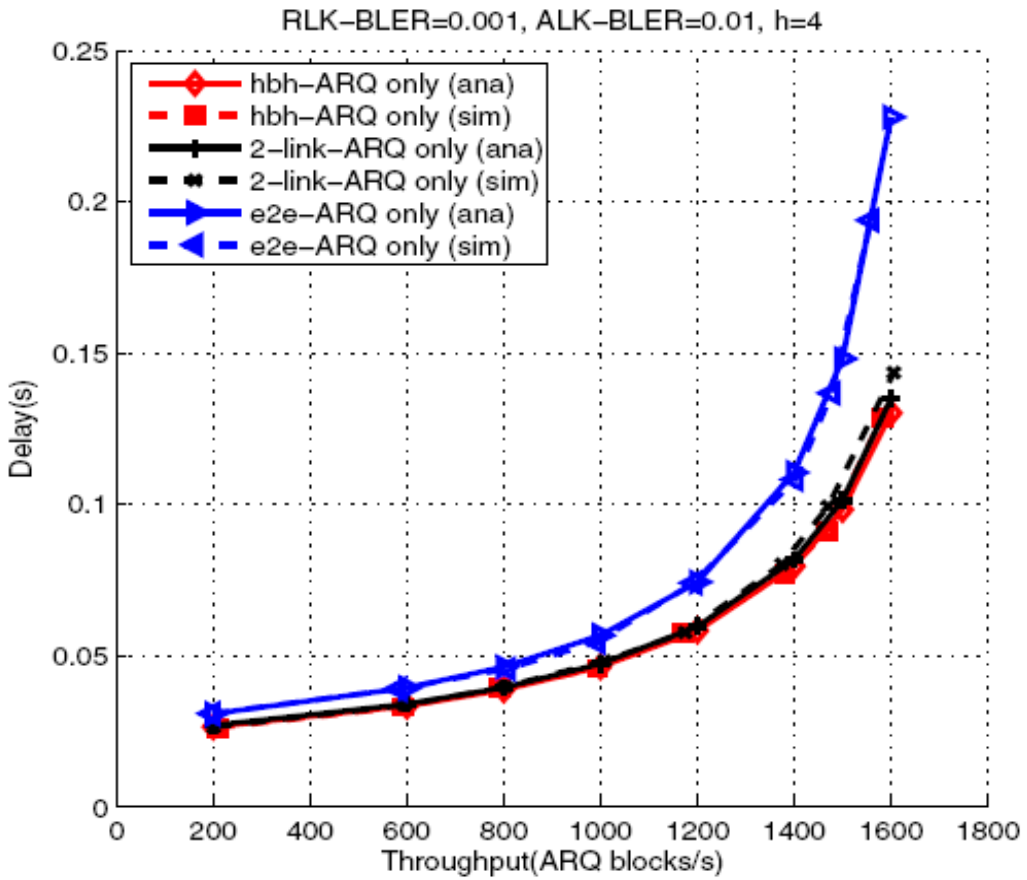
- The delay for the proposed method is:

$$\overline{D}_{AH}(h) = \overline{T}_{AH}(h, \{\mathbf{p}_a^{h-1}, p_{r_h}\})$$

$$T_{ACK}^{AH} = \sum_{i=1}^{m-1} \frac{1}{\mu_i} + \frac{1}{\mu_h^H} + mT_p + T_H < T_{ACK}^{H}$$

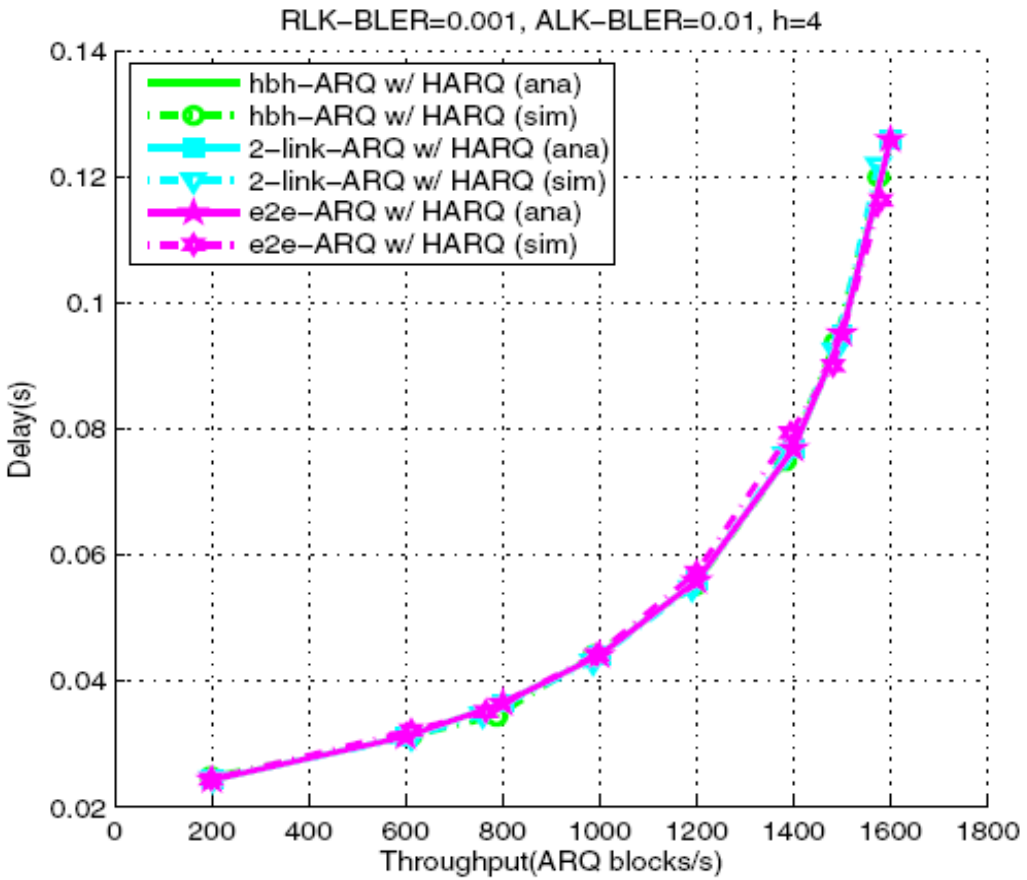
Only access link applies HARQ

Performance Evaluations



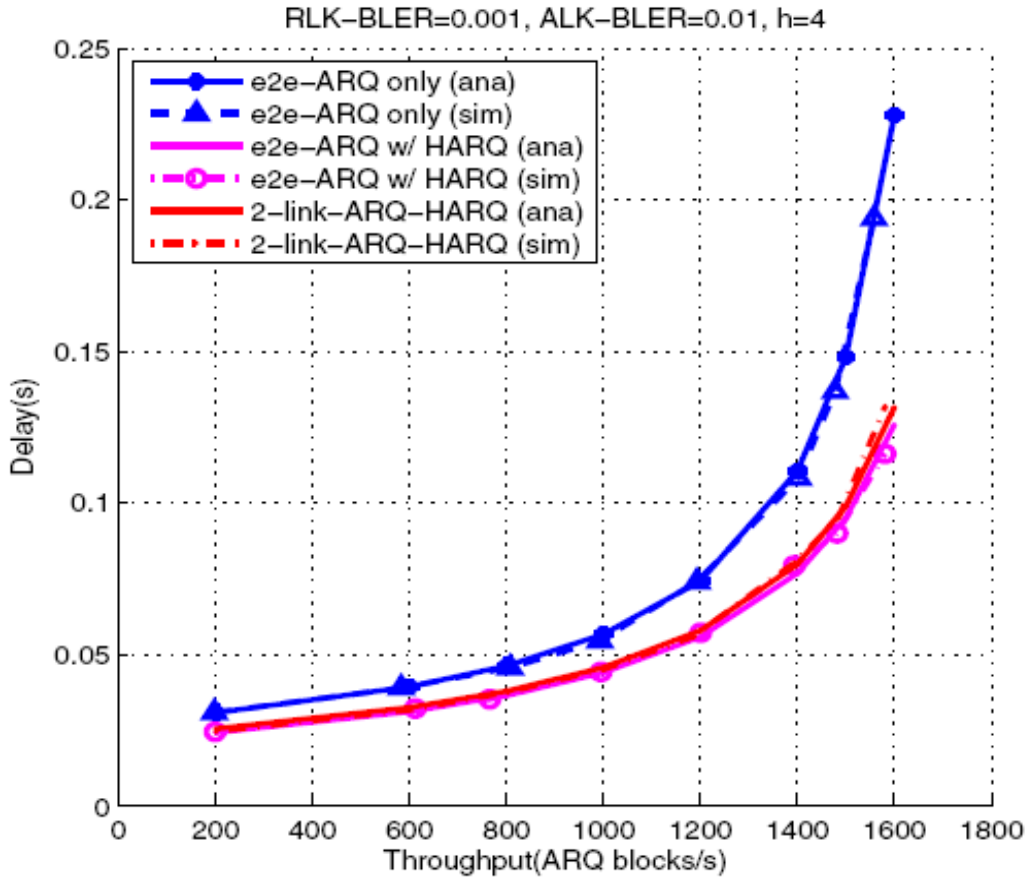
ARQ Only

Performance Evaluations



ARQ with HARQ

Performance Evaluations



Proposed ARQ vs End-to-End ARQ

Conclusions

- Error controls for multi-hop relay environment are analyzed
  - The analytical model tells that pure ARQ do not perform well in the multi-hop network
  - Retransmission timer has to increase as the number of hop increases
    - Due to longer delay for retransmission
- HARQ can be used in single-hop, but not in multi-hop
  - Error introduced at intermediate RSs will increase since error probability increases with hop-count also
- Compared with End-to-End ARQ with per-hop HARQ, The proposed combination of ARQ and HARQ provide
  - Lower complexity
  - Less information exchange during handover process