Flow Control in Relay Enhanced IEEE 802.16 Networks

17. ComNets-Workshop Mobil- und Telekommunikation

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Outline

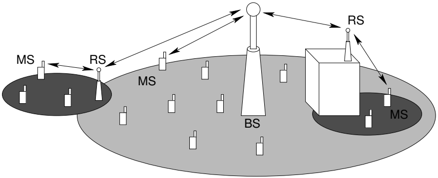
Beyond 3rd Generation (B3G) Mobile Radio Networks

Requirements for future IMT-Advanced compliant systems

- Cell throughput higher than 100 Mb/s for high mobility applications
- Peak cell throughput up to 1 Gb/s for low mobility applications
- Ubiquitous coverage also at the cell edge
- High quality mobile services

➥ New deployment concepts for mobile communications infrastructure necessary

Relay Enhanced Cells



Relay Stations (RSs) may be used

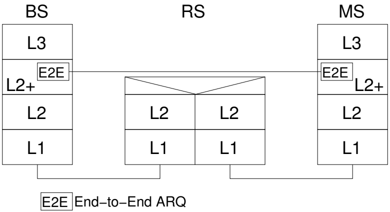
- to serve areas of the cell poorly covered by the Base Station (BS)
- to enhance the coverage area of a cell (expected to be applied mainly during roll-out)

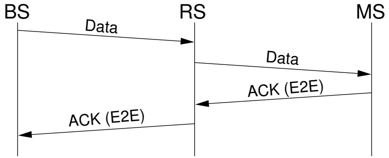
IMT-Advanced systems must provide the reliable transmission of data also for Mobile Stations (MSs) connected to the BS via an RS (e.g. to avoid TCP to misinterpret IP packets lost due to transmission errors as congestion)

➥ Automatic Repeat Request (ARQ) protocols have to be employed

But: Are ARQ protocols sufficient for reliable transport of data while maximizing the cell capacity?

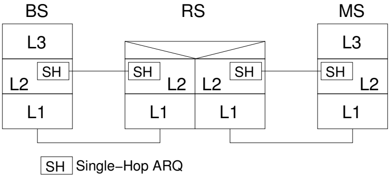
End-to-End ARQ

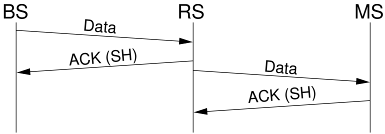




- Provides reliable transport of data over an arbitrary number of hops
- Reduces probability of frame loss due to buffer overflows when the capacity of the sliding window is smaller or equal to the capacity of the smallest buffer at the RSs
- Simple to implement
- Frames lost on the second hop have to be retransmitted also on the first hop
- Long retransmission timeouts as transmission time over multiple hops is hard to estimate (e.g. due to residence time in buffers at the RSs)
- Buffer overflows cannot be excluded

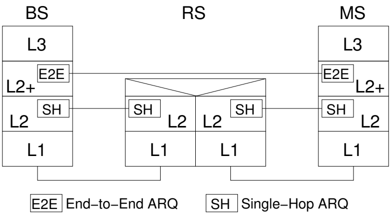
Hop-by-Hop (H)ARQ

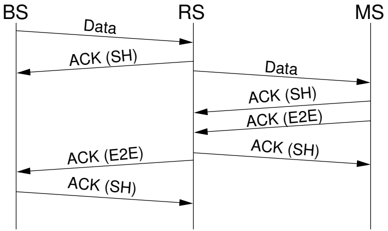




- Frames have to be retransmitted only on that hop they have been lost on
- Short retransmission timeouts of few frame durations are feasible as transmission on the hop can be well estimated
- Different ARQ strategies may be applied on the different hops exploiting channel conditions (BS↔RS usually Line-of-Sight (LoS), RS↔MS LoS or non-LoS)
- No reliable end-to-end transport of data guaranteed (frames lost due to buffer overflows at RSs are not retransmitted)
- ARQ context transfer during hand-over not easily feasible

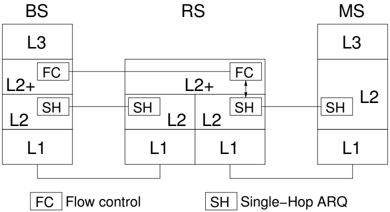
Layered ARQ

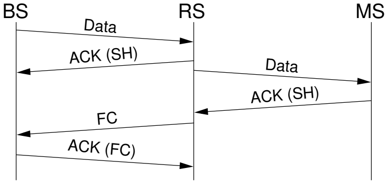




- Frames have to be retransmitted only on that hop they have been lost on
- Short retransmission timeouts of few frame durations are feasible for the SH-(H)ARQs
- Different ARQ strategies may be applied for the SH-(H)ARQs on the different hops exploiting channel conditions (BS↔RS usually Line-of-Sight (LoS), RS↔MS LoS or non-LoS)
- Reliable end-to-end transport of data guaranteed
- Retransmission timeouts of different ARQs have to be coordinated (otherwise unnecessary retransmissions may occur)
- Buffer overflows cannot be excluded

Relay ARQ

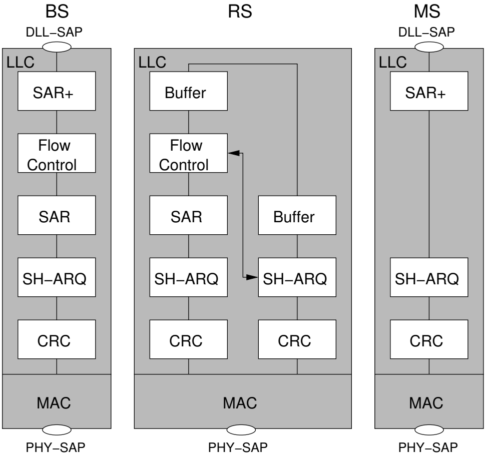




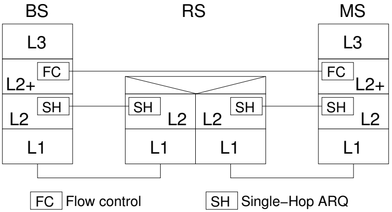
- Frames have to be retransmitted only on that hop they have been lost on
- Short retransmission timeouts of few frame durations are feasible for the SH-(H)ARQs
- Different ARQ strategies may be applied for the SH-(H)ARQs on the different hops exploiting channel conditions
- Reliable end-to-end transport of data guaranteed
- Flow control and SH-(H)ARQ on second hop need to use same sequence numbers
- LLC layer at the BS differs for RSs and MSs

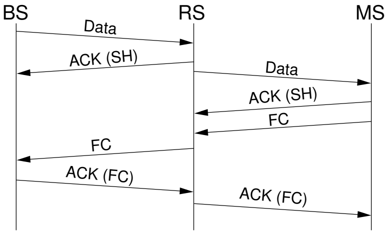
Relay ARQ (cont.)

- Frames on the first hop may be segmented in other sizes than on the second hop
- Additional complexity due to multi-hop transmissions is limited to BSs and RSs
- Fragment size at the flow control instance has to fit the (H)ARQ block size on the second hop
- Close coupling between flow control and ARQ results in high protocol and implementation complexity
- Segmentation of frames for the second hop has to be done at the BS already



Distributed ARQ and Flow Control

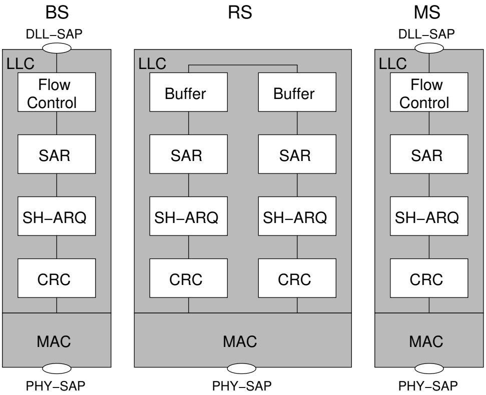




- Frames have to be retransmitted only on that hop they have been lost on
- Short retransmission timeouts of few frame durations are feasible for the SH-(H)ARQs
- Different ARQ strategies may be applied for the SH-ARQs on the different hops exploiting channel conditions
- Reliable end-to-end transport of data guaranteed
- An additional message exchange applies on the second hop

Distributed ARQ and Flow Control (cont.)

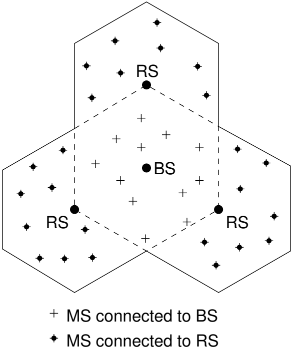
- Flow control and SH-(H)ARQ on second hop may use different sequence numbers and frame/block sizes
- Flow control and (H)ARQ are completely independent resulting in lower complexity of each individual protocol
- Any SH-(H)ARQ strategy may be used in multi-hop scenarios without modifications
- Increased complexity of MSs



Setup

Table: Simulation Parameters

MSs per BS	12
MSs per RS	8
BS MA scheme	TD-/SDMA
BS antenna pattern	adaptive (beam-forming)
BS max. beams	4
RS MA scheme	TDMA
RS antenna pattern	adaptive (beam-forming)
MS antenna pattern	omni-directional
Standard	IEEE 802.16-2009
Scenario type	coverage enhancement
Cell radius	750 m
MAC PDU size	3000 bit
PDU IAT	fixed



Preliminary Results

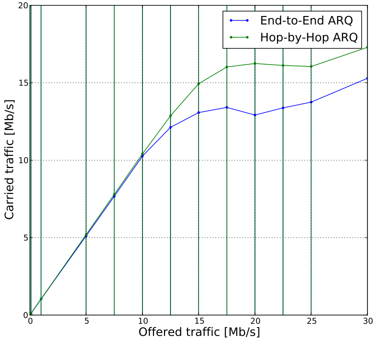


Figure: DL traffic per cell

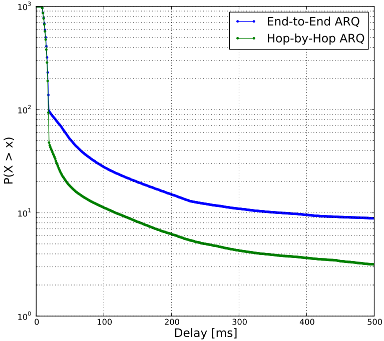


Figure: Complementary Cumulative Density Function (CCDF) of the MAC PDU transmission delay for two-hop connections

Conclusions

- In multi-hop scenarios flow control is necessary to maximize cell capacity
- Separation of ARQ and flow control functionality
  - reduces complexity of the individual protocol functions
  - improves reusability through modularity (transfer of the ISO/OSI layer concept into the layer)
  - simplifies implementation and validation
- Advantages and disadvantages of the Relay ARQ and the distributed ARQ/Flow control concept need to be investigated by simulation

Thank you for your attention!