Factors that affect performance of a mobile multihop relay system

IEEE 802.16 Presentation Submission Template (Rev. 8.3)

Document Number:

IEEE C802.16mmr-05/017r1

Date Submitted:

2005-09-13

Source:

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Venue:

IEEE 802.16 Session #39, Taipei, TAIWAN

Base Document:

None

Purpose:

Response to a call for contributions to the mobile multihop relay study group.

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 - Factors that affect multi-hop gain
- Requirements of a multi-hop relay system



EU IST-ROMANTIK Project

ResOurce Management and AdvaNced Transceiver AlgorIthms for Multihop NetworKs



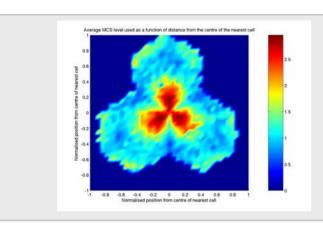
Partners

- Universitat Politècnica de Catalunya, Spain
- University of Bristol, UK
- University of Rome, Italy
- Dune, Italy
- Intracom, Greece
- Fujitsu Labs of Europe, UK
- Telenor, Norway

Feb 2002 → April 2005



Motivation for multi-hop



- High Data rates in centre of cell
- Low Data rates at cell edge
- How to increase data rates at cell edge:
 - ⇒ Decrease size of cell vs. use multi-hop?

Reduce cell size

• End up providing capacity in excess of requirement?

Multi-hop

- Can cell edge rates be improved upon in interference limited case?
- What is the impact on capacity?
- Is it a more cost effective solution?



Relay Types: Two basic definitions

Amplify and Forward (A&F)

- Mainly considered as a dummy repeater
- Cheap and simple to deploy/maintain
- RRM and scheduling performed at BS
- Difficult to achieve single frequency re-use

Decode and Forward (D&F)

- Includes full baseband functionality
- Similar to micro/pico cell BS
- Still controlled by the BS
- Co-operates with BS in RRM and scheduling
- Scheduling can be simple FIFO or more advanced
- Enables advanced techniques such as coordinated interference management and cooperative transmission



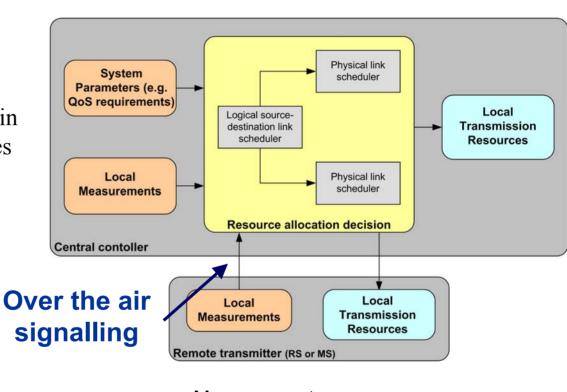


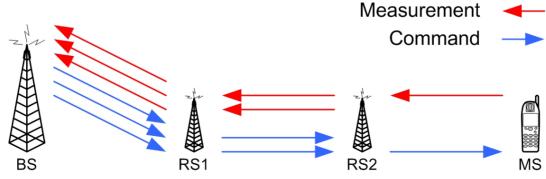


RRM Strategies

Centralised

- RRM performed in BS
- All measurements collated in BS and all control originates from BS
- + Handover easier to manage
- + Lower complexity RS
- Latency in response
- Signalling overhead large

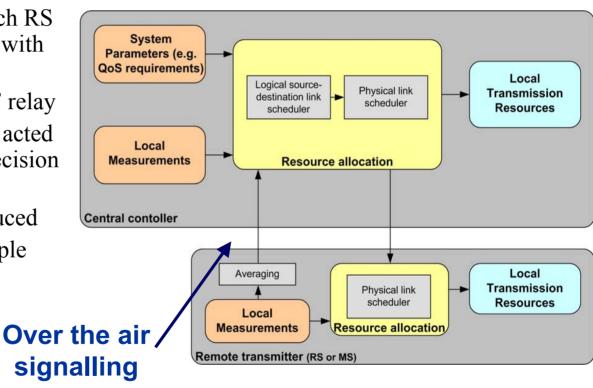




RRM Strategies

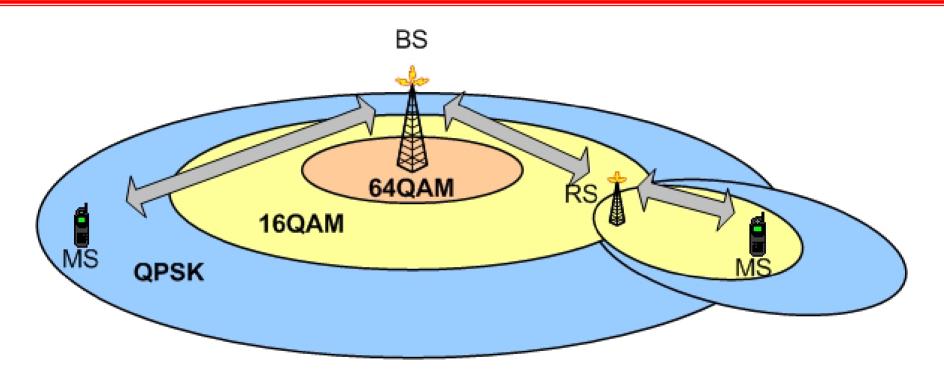
Decentralised

- RRM is performed at each RS (possibly in conjunction with BS)
- Not possible for an A&F relay
- Local measurements are acted upon locally and final decision made locally
- + Signalling overhead reduced
- + Easily scalable for multiple hops
- + Lower latency
- Higher complexity RS
- Handover issues





Coverage Augmentation

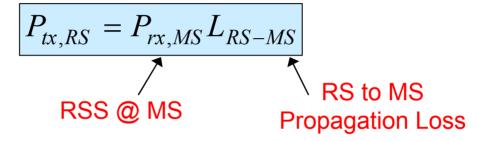


- Analyse the link budget to determine:
 - The effect on the received signal strength
 - The effect on the SNR or throughput



Received Signal Strength

• For a given MS receiver sensitivity, the transmit power at RS must be set such that:



• Assuming that the received sensitivity requirements at RS and MS are the same:

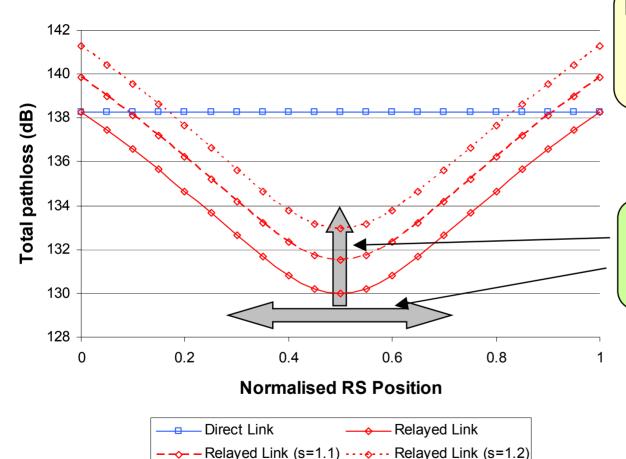
$$P_{tx,total} = P_{rx,MS} \left(L_{BS-RS} + L_{RS-MS} \right)$$

• As a result it is possible to define:

$$G_{m} = \frac{P_{tx,direct}}{P_{tx,relayed}} = \frac{L_{BS-MS}}{L_{BS-RS} + L_{RS-MS}}$$



Pathloss Analysis: RS Position

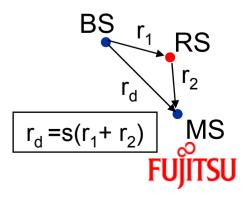


Propagation loss model:

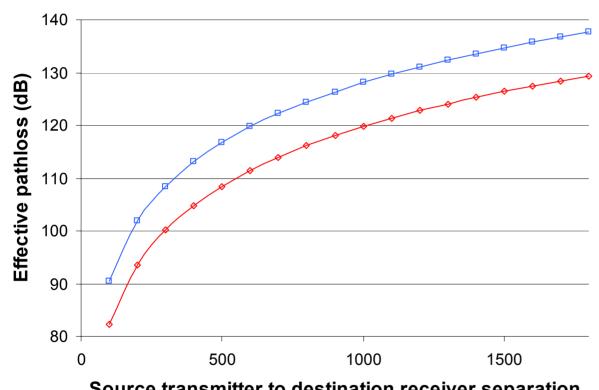
$$L(dB) = b + 10n \log r$$

Where: b=15.3, n=3.76

Effect of RS positioning



Range Extension



Source transmitter to destination receiver separation (metres)



Assumes:

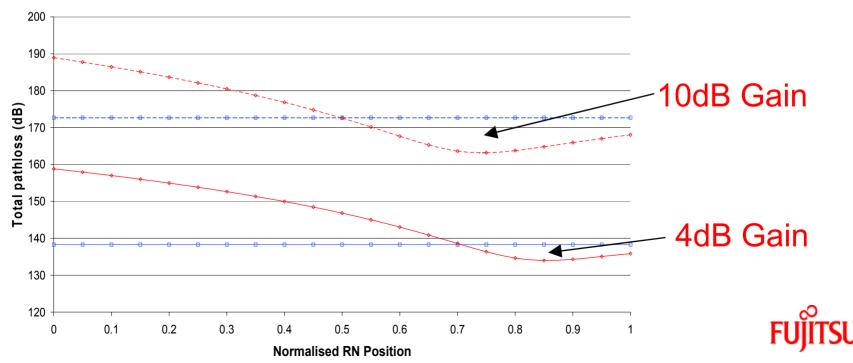
- Optimal RS position of half BS-MS separation
- Symmetric link propagation properties



Pathloss Analysis: Different Link Parameters

- In reality propagation parameters of each link will not be equal
- Using modified 3GPP model/UoB models shows region of gain is reduced

Pathloss Parameter		Link		
		BS-MS	BS-RS	RS-MS
3GPP	b (dB)	15.3	15.5	28
	n	3.76	3.68	4
UoB	b(dB)	13.07	16.29	10.04
	n	4.88	4.64	5.47



Received Signal Strength

- For no increase in total transmit power:
 - Range extension of an RSS
 - → Improvement in RSS at a particular point

- OR -

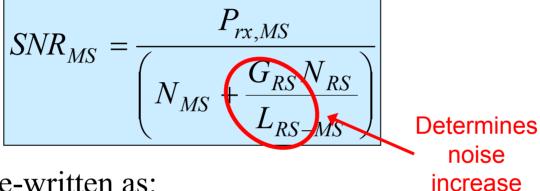
- Reduction in transmit power to provide same RSS
 - → Reduction in the level of interference experienced

- Gain dependent on:
 - RS positioning
 - Propagation properties



Received SNR for A&F

• For the case of an A&F relay, the SNR at the MS is given by:



This can be re-written as:

$$SNR_{MS} = \frac{P_{tx,RS}}{L_{RS-MS}} + \frac{P_{tx,RS}}{SNR_{S}L_{RS-MS}}$$
 BS tx power

SNR at MS is a function of RS and BS transmit power

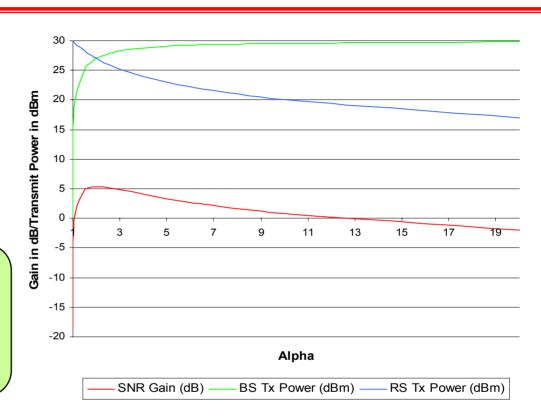


Received SNR for A&F

- Symmetrical pathloss parameters
- RS midway between
 BS and MS

For an A&F relay:

- SNR gain of ~5.3dB
- RSS gain of ~8.3dB



$$G_{SNR,m} = \frac{SNR_{MS,relayed}}{SNR_{MS,direct}} = \frac{L_{BS-MS}}{\alpha \left(L_{RS-MS} + \frac{L_{BS-RS}}{(\alpha - 1)}\right)}$$

$$\alpha = \frac{P_{tx,tot}}{P_{tx,RS}}$$
TUJITSU

Received SNR for D&F

• For the case of an D&F relay, the SNR at the MS is given by:

• However, in the D&F case the average throughput at the MS is given by:

$$T_{MS,relayed} = T_{BS} (1 - BLER_{BS-RS}) (1 - BLER_{RS-MS})$$

- This is based on the assumption that when an error is detected at the RS, the data is not relayed to the MS.
- Careful setting of BS and RS transmit power is required to:
 - Maximise the achieved throughput
 - Prevent excess radiation of transmit power

Summary of theoretical benefits

- Theoretical analysis implies multihop should provide a coverage and throughput enhancement
- Possible to infer reduction in interference
- System simulation showed that for no extra transmission resource requirement (see paper in IEEE VTC Fall '05):
 - Improvement in user throughput was possible
 - Increase in system capacity
 - Possible to manage impact on latency \rightarrow use of schedulers

However, all of these benefits are dependent on careful RS positioning and transmit power setting



Considerations for a multihop relay system

- Consider the complexity of the RS
 - Fully featured BS vs. Dummy Repeater
 - RRM strategy for scheduling (Centralised vs. Decentralised)
- Impact of different RS types and RRM strategies:
 - Signalling load of responses & requests vs. management of handover
- Mechanisms to automate optimal operation → essential to prevent loss in capacity
 - Relay position may change
 - Deployment position may not be planned
- Mechanisms to exploit distributed nature of the transmitters
 - Co-operative transmission (exploiting spatial/time diversity)
 - Interference aware scheduling



Some fundamental questions

- Is the mobile multihop relay system to purely increase range/user throughput?
 - Should this be at the expense of capacity?
 - Or should we also use RS to try and increase capacity as well?
- Do we want RS to be easy to deploy and install?
 - Mechanisms within the RS to enable this, optimising performance once deployed
 - Or will we have a relay scheme that requires careful deployment dimensioning & radio planning (and thus high engineering costs)?

