

Factors that affect performance of a mobile multihop relay system

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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



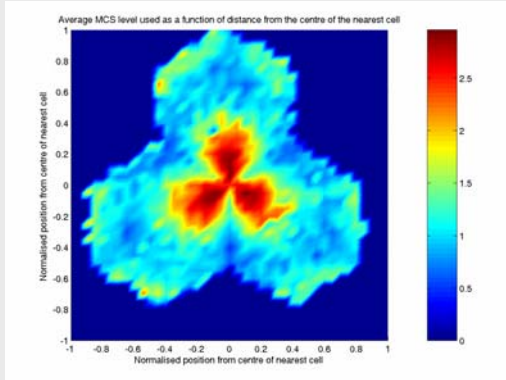
Partners

- 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



Low complexity

- **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

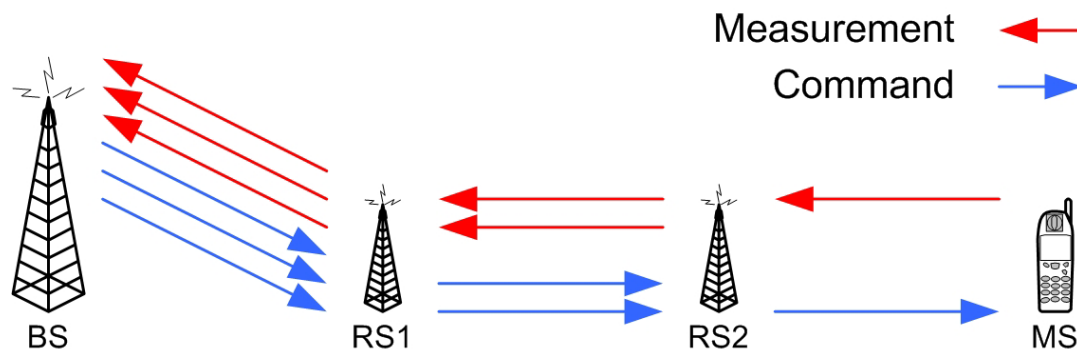
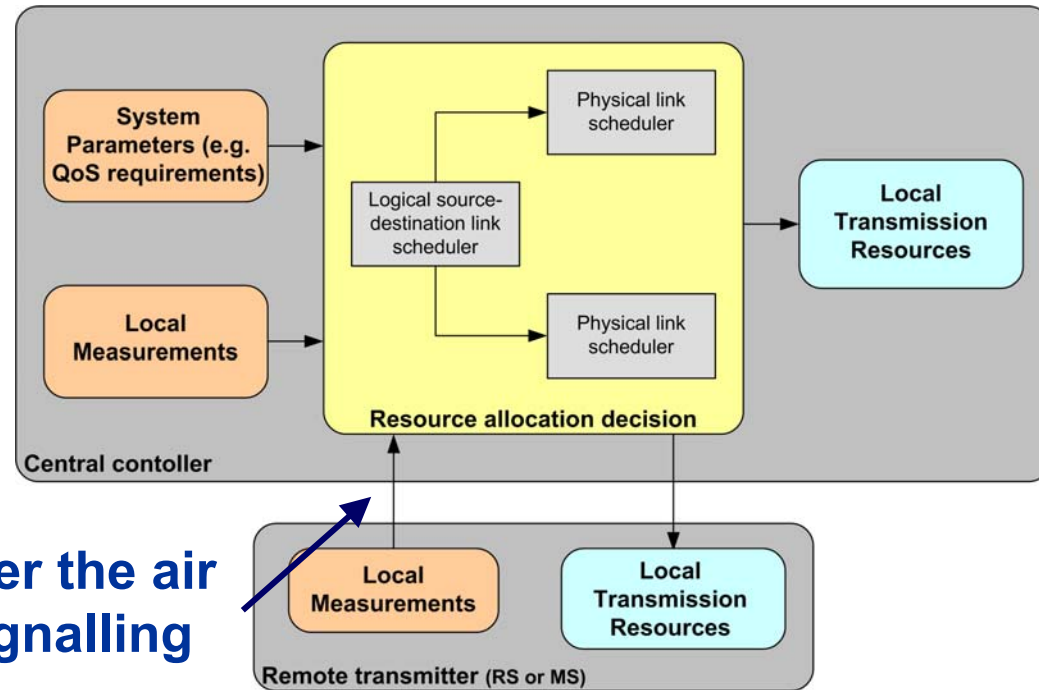


High complexity

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

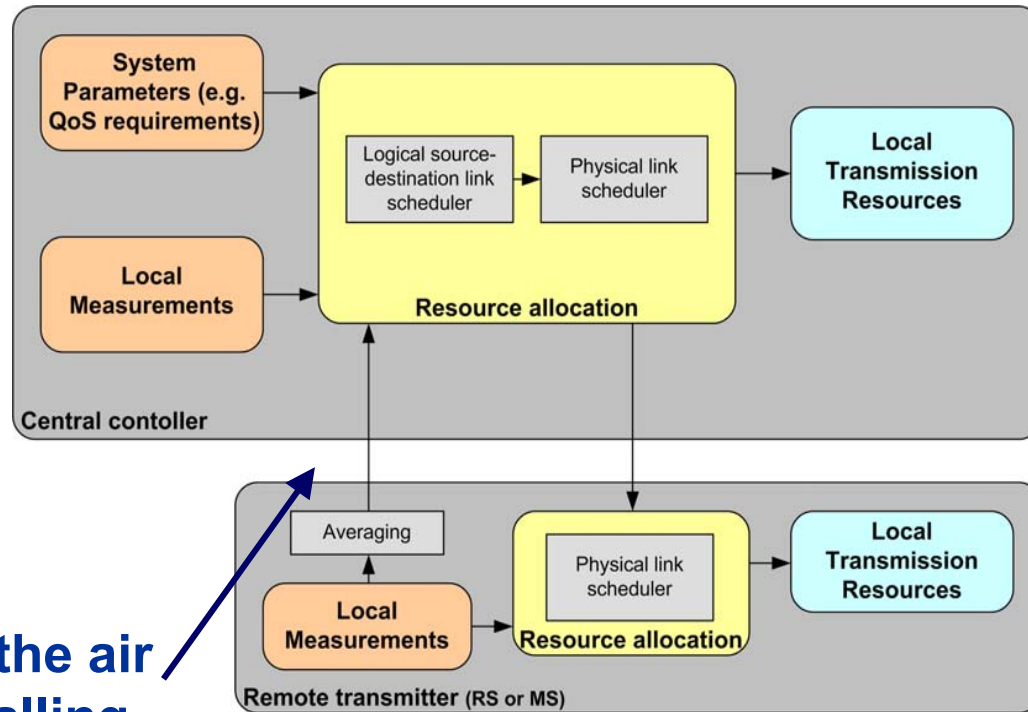


RRM Strategies

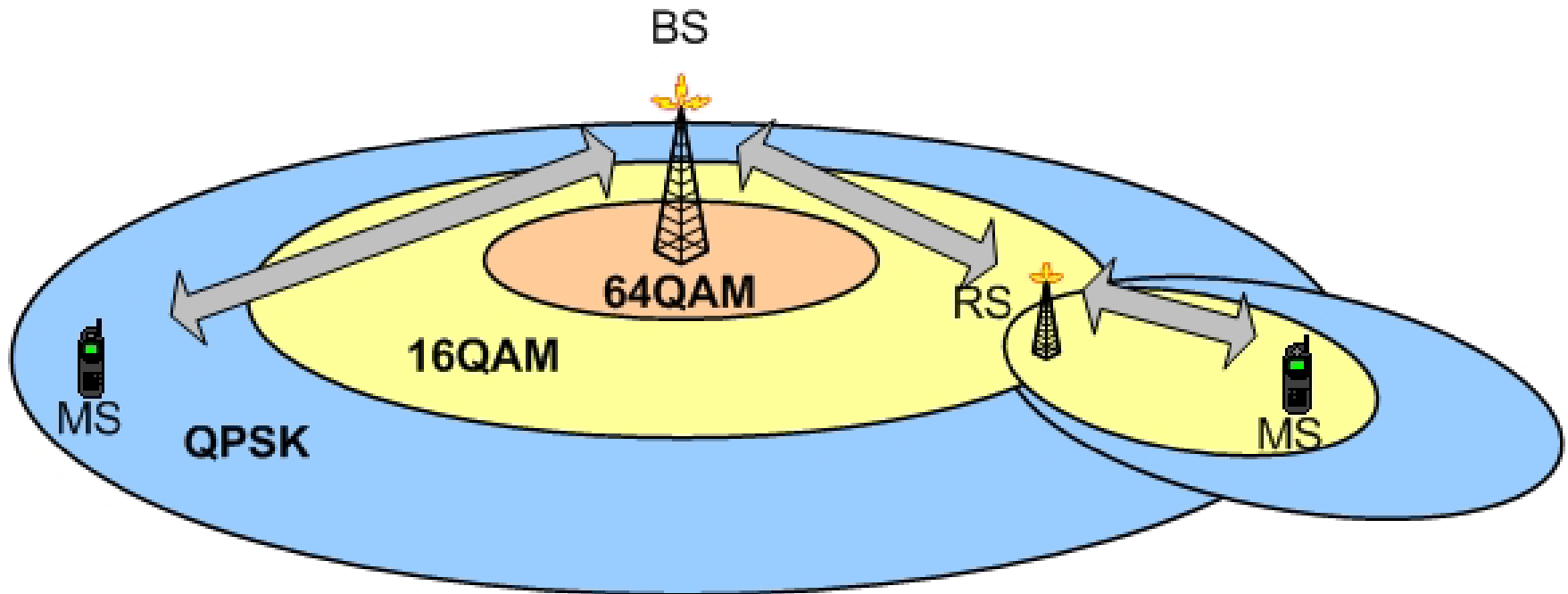
- **Decentralised**

- 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

Over the air signalling



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:

$$P_{tx,RS} = P_{rx,MS} L_{RS-MS}$$

RSS @ MS

RS to MS Propagation Loss

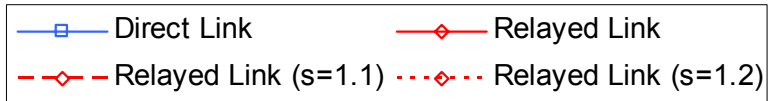
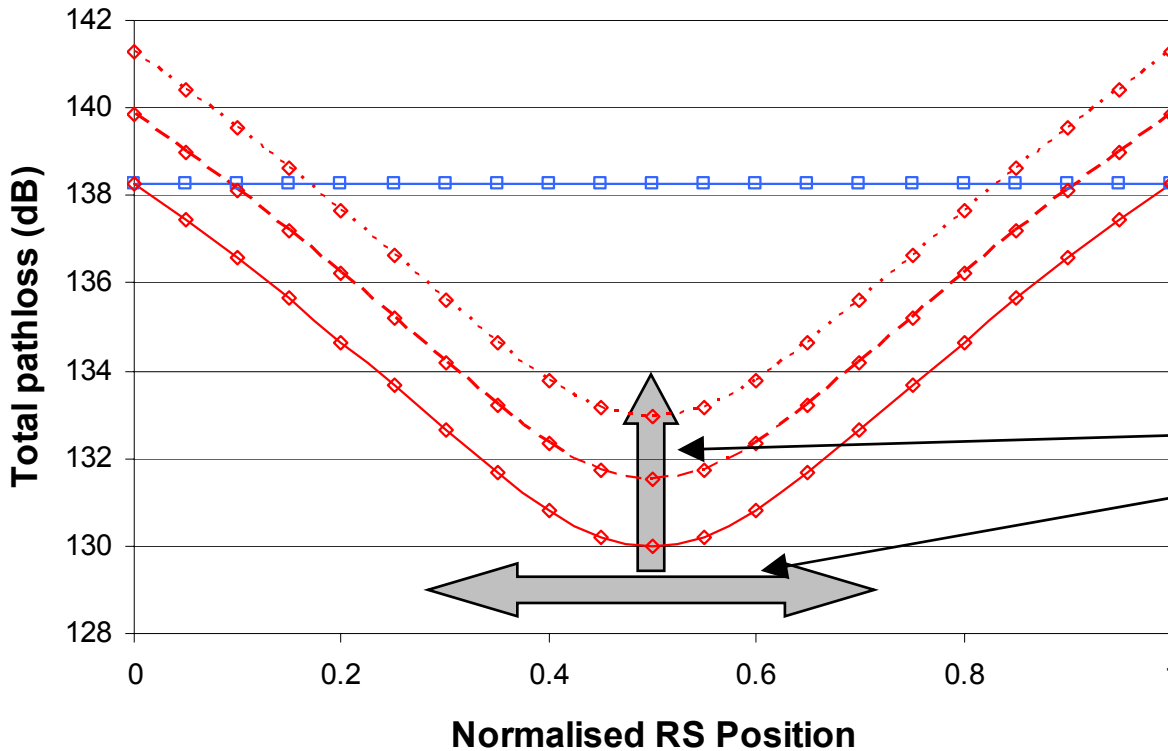
- Assuming that the received sensitivity requirements at RS and MS are the same:

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

- 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

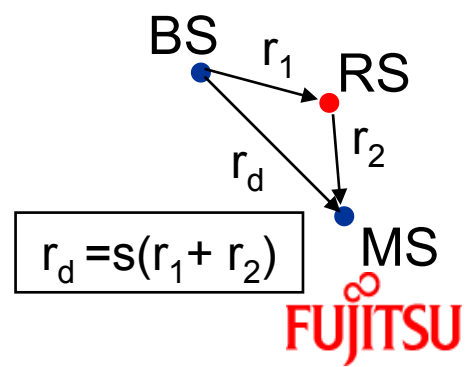


Propagation loss model:

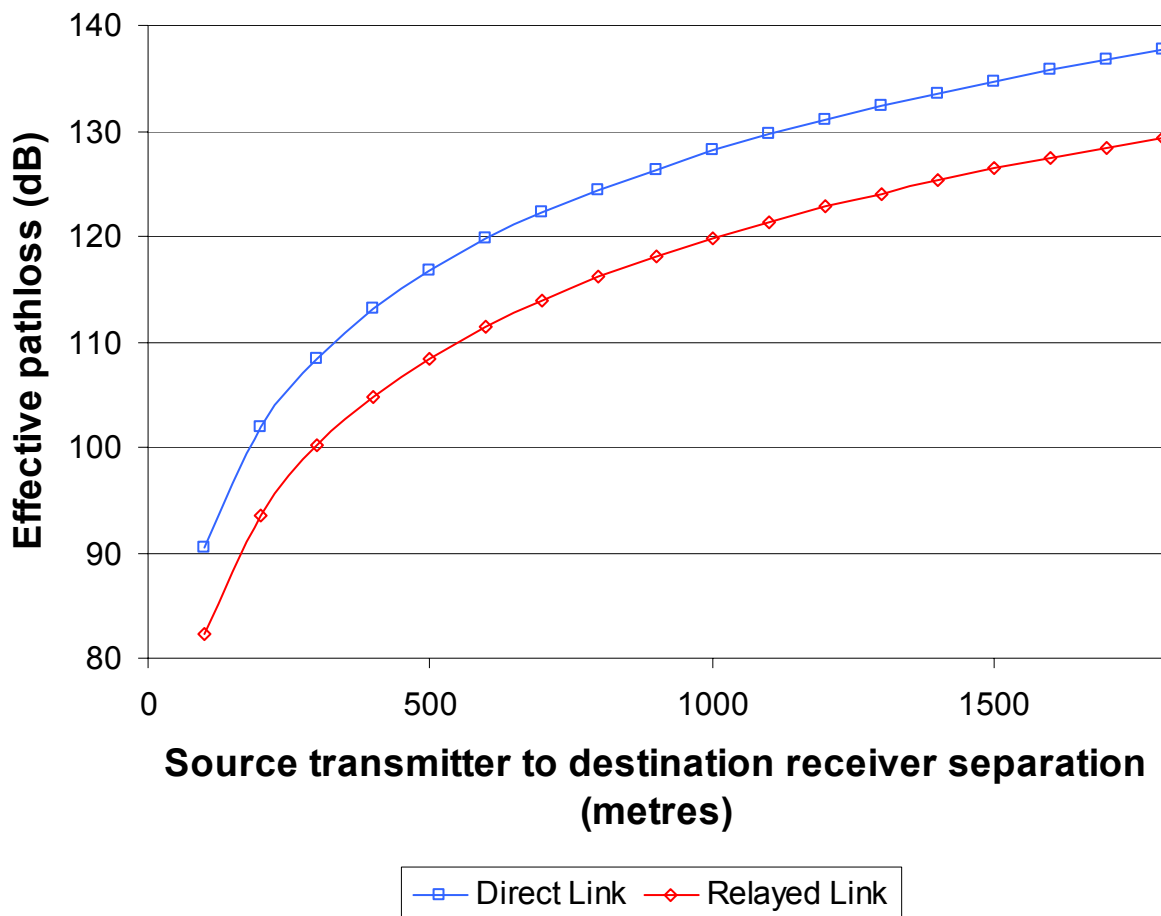
$$L(dB) = b + 10n \log r$$

Where: $b=15.3$, $n=3.76$

Effect of RS positioning



Range Extension



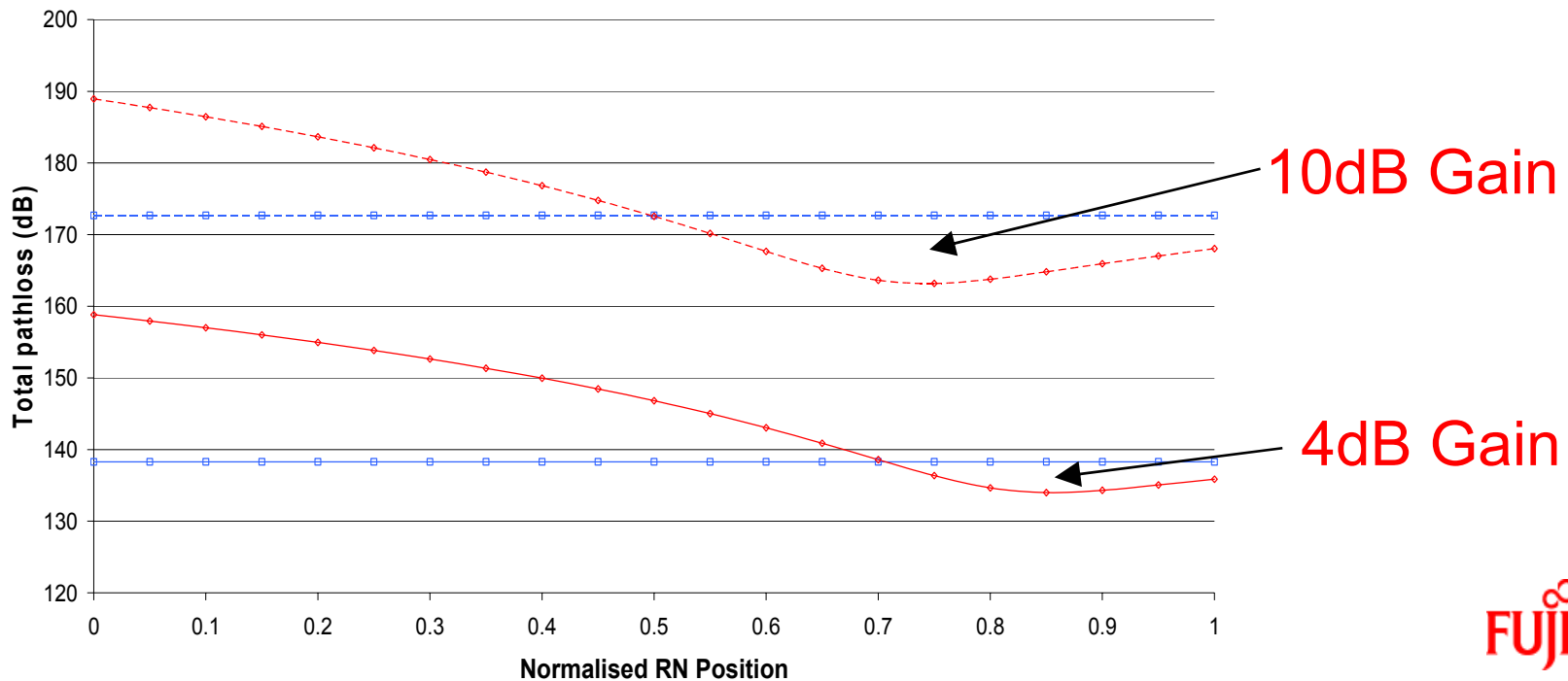
Assumes:

- 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:

$$SNR_{MS} = \frac{P_{rx,MS}}{\left(N_{MS} + \frac{G_{RS} N_{RS}}{L_{RS-MS}} \right)}$$

Determines noise increase

- This can be re-written as:

$$SNR_{MS} = \frac{P_{tx,RS}}{L_{RS-MS} \left(N_{MS} + \frac{P_{tx,RS}}{SNR_{RS} L_{RS-MS}} \right)}$$

RS tx power

BS tx power

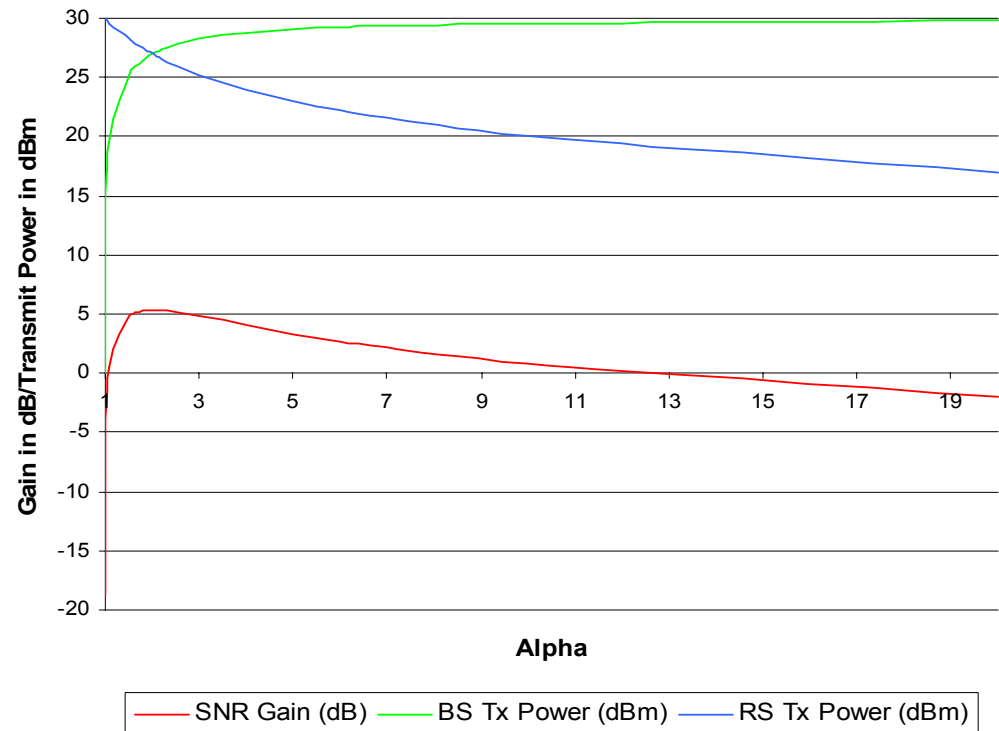
SNR at MS is a function of RS and BS transmit power

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



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

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



Received SNR for D&F

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

$$SNR_{MS} = \frac{P_{rx,MS}}{N_{MS}}$$

← No noise amplification at RS

- 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 → 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