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:
Mike Hart, Sunil Vadgama
Fujitsu Laboratories of Europe Ltd.
Hayes Park Central, Hayes, Middx.
UK, UB4 8FE
Voice: +44 20 8606 4523
Fax: +44 20 8606 4539
E-mail: mike.hart@uk.fujitsu.com

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.

Contents

- Motivation for exploring multi-hop techniques
- Relay capability & RRM requirements
- Coverage augmentation (pathloss analysis)
  - Effect of multi-hop on received signal power
  - Effect of multi-hop on SNR and throughput
  - Factors that affect multi-hop gain
- Requirements of a multi-hop relay system

EU IST-ROMANTIK Project

Res**O**urce **M**anagement and
Adva**N**ced **T**ransceiver Algor**I**thms
for Multihop Networ**K**s

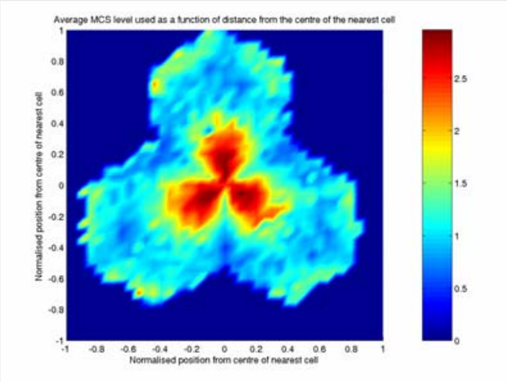
Partners

- 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

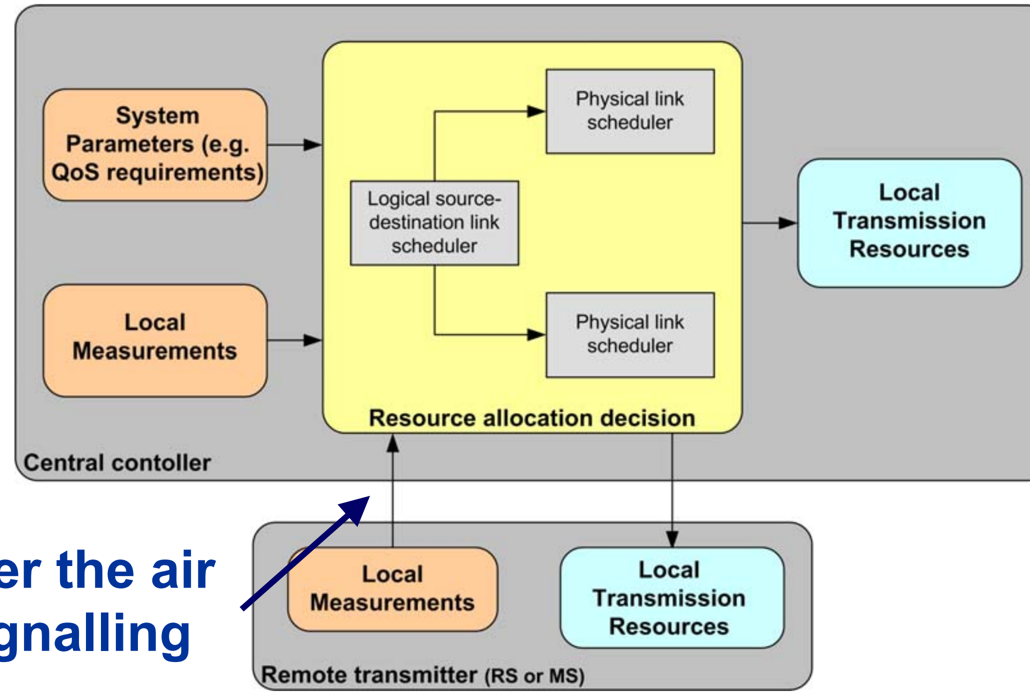
→ Low complexity

- **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 co-ordinated interference management and co-operative transmission

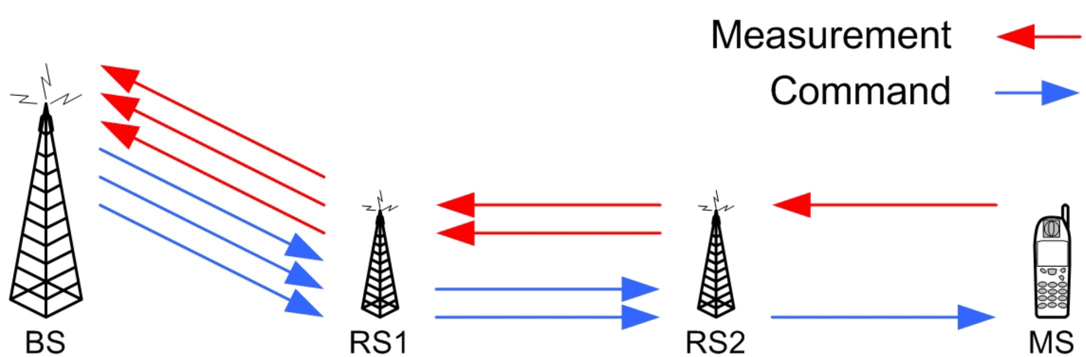
→ High complexity

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

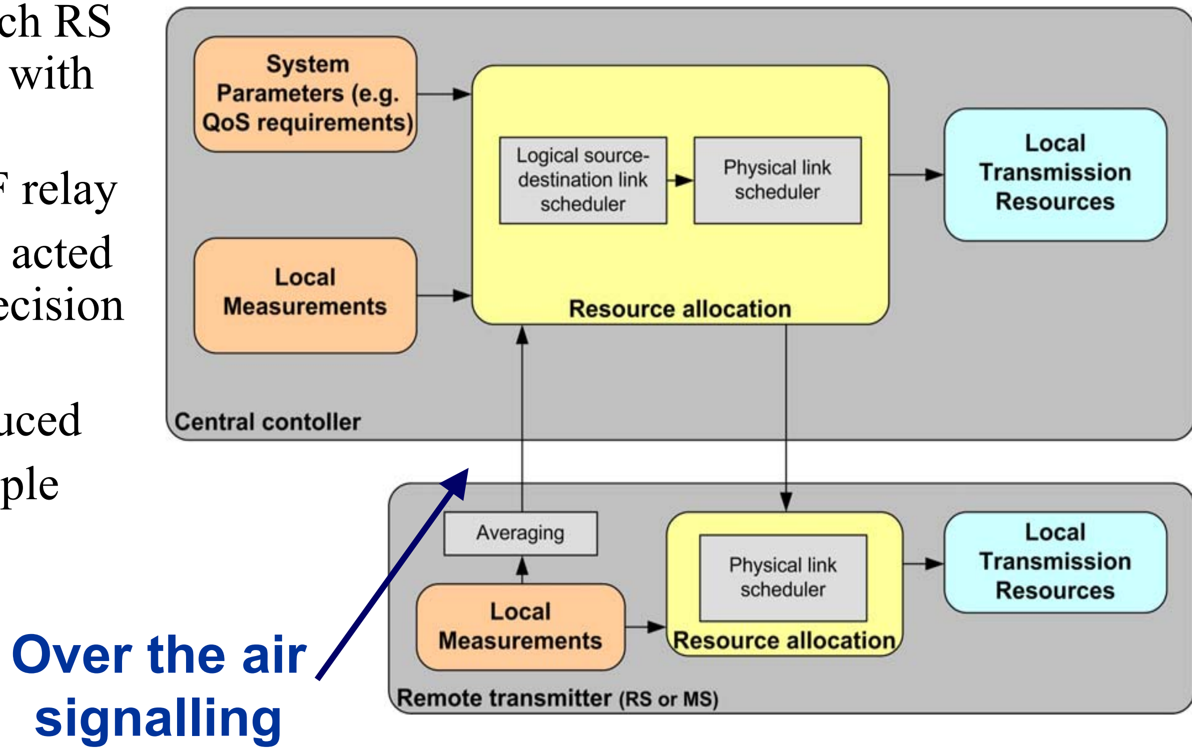


Over the air signalling



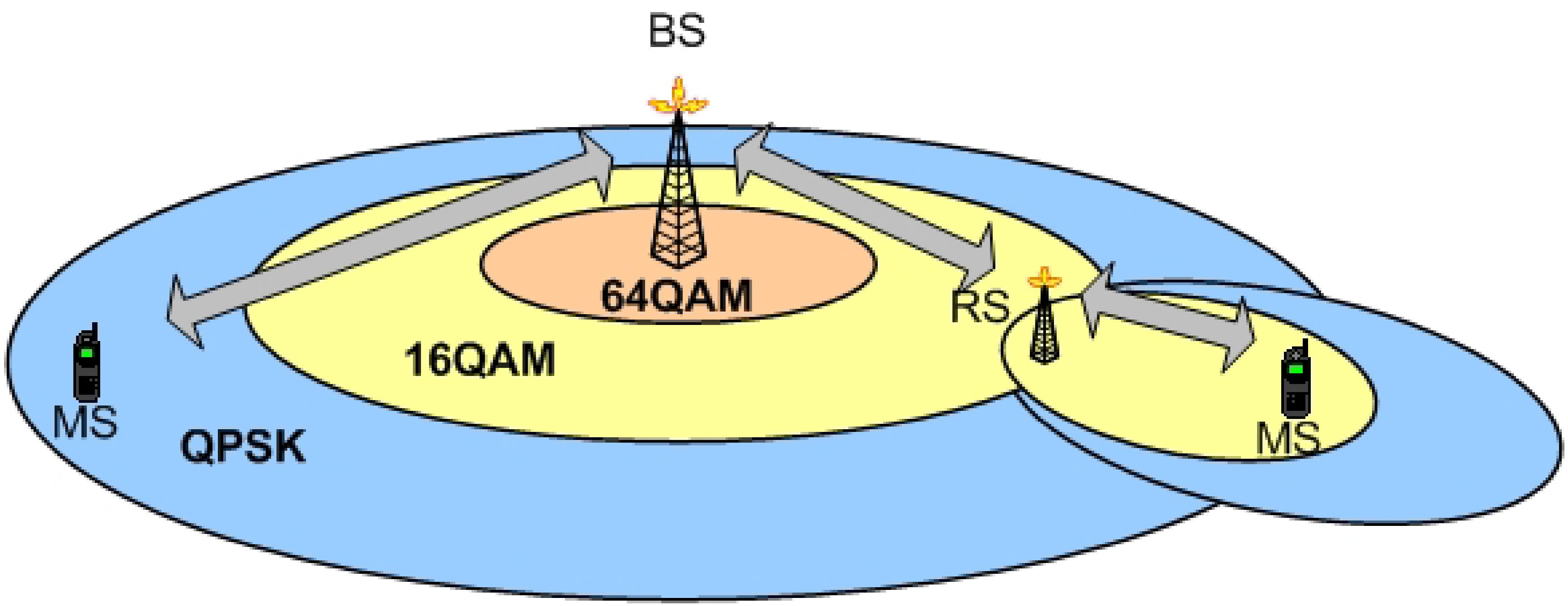
RRM Strategies

- **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



FUJITSU
THE POSSIBILITIES ARE INFINITE

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

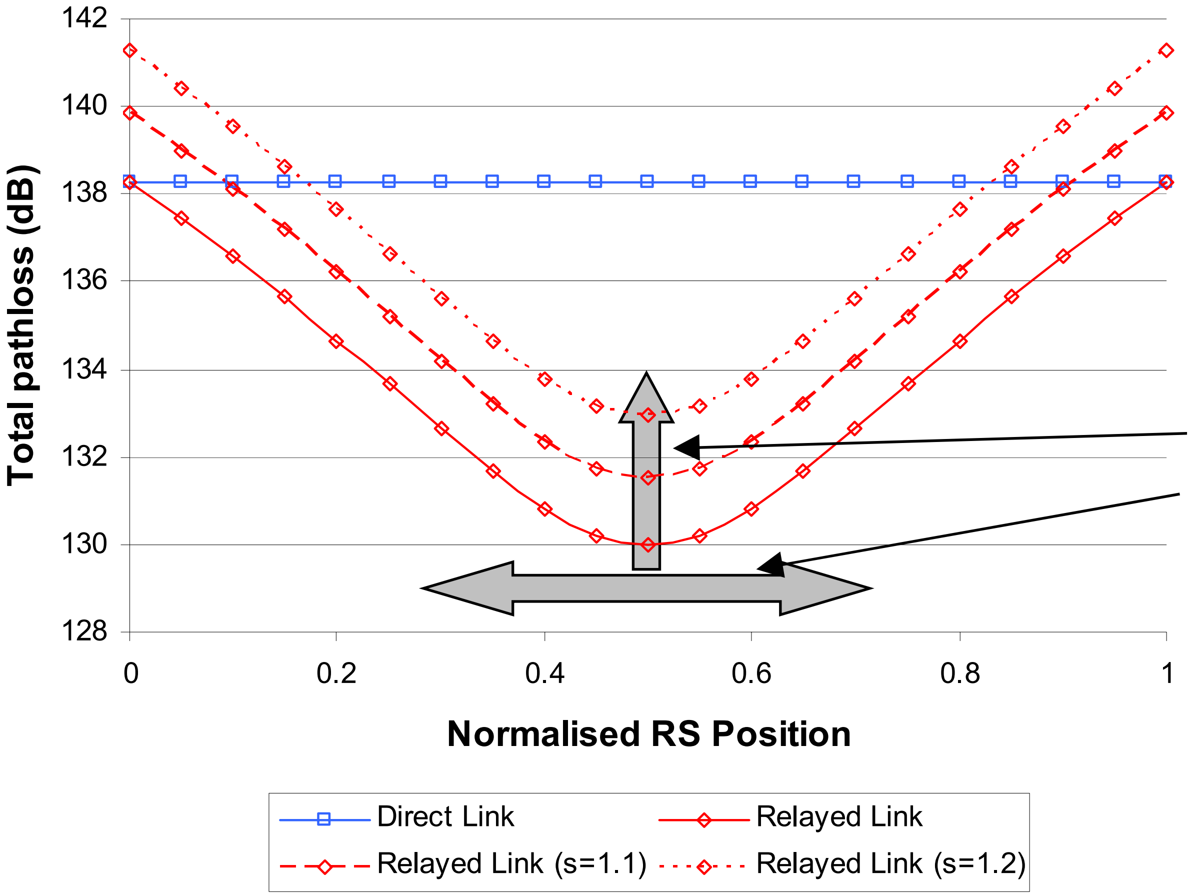
- Assuming that the received sensitivity requirements at RS and MS are the same:

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

- 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

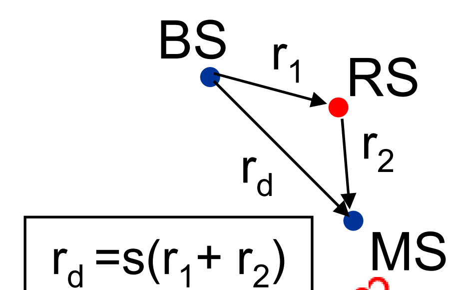


Propagation loss model:

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

Where: b=15.3, n=3.76

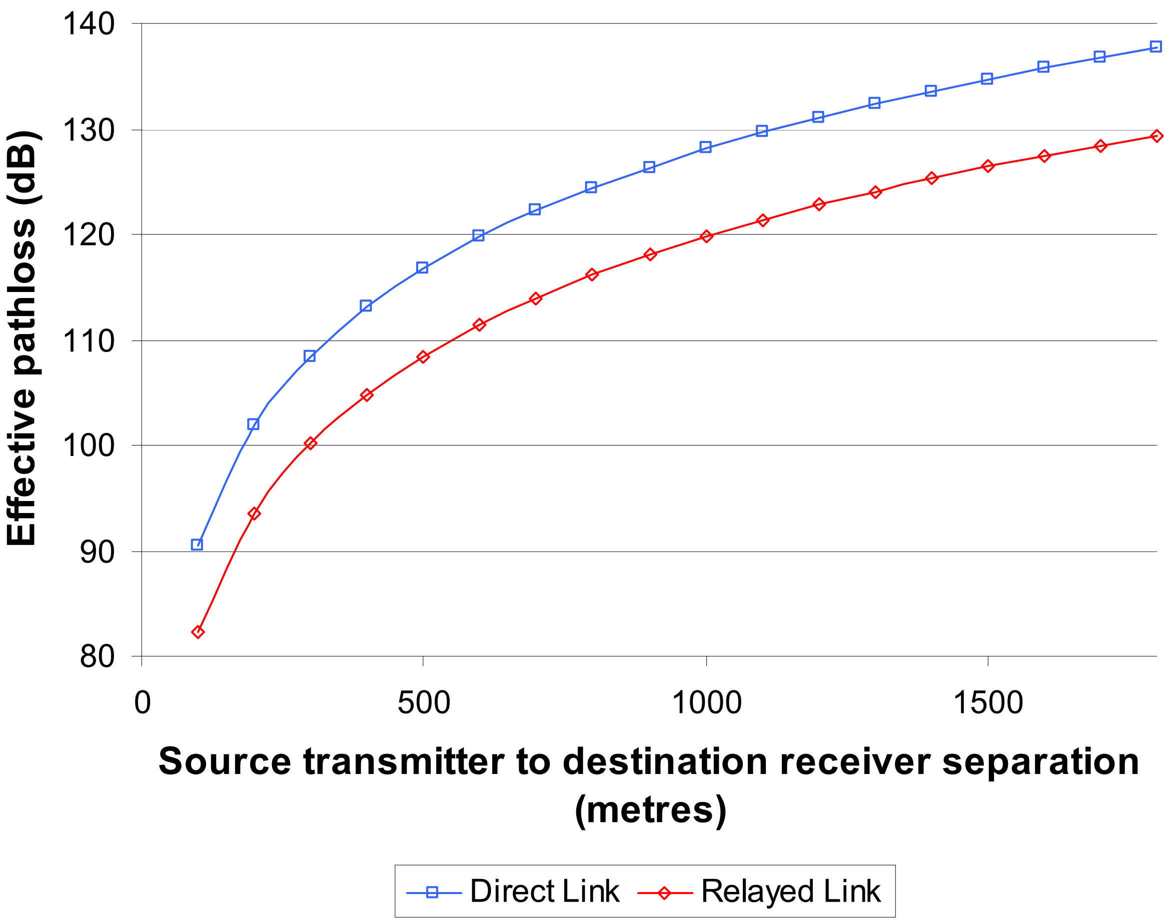
Effect of RS positioning



FUJITSU

THE POSSIBILITIES ARE INFINITE

Range Extension



Assumes:

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

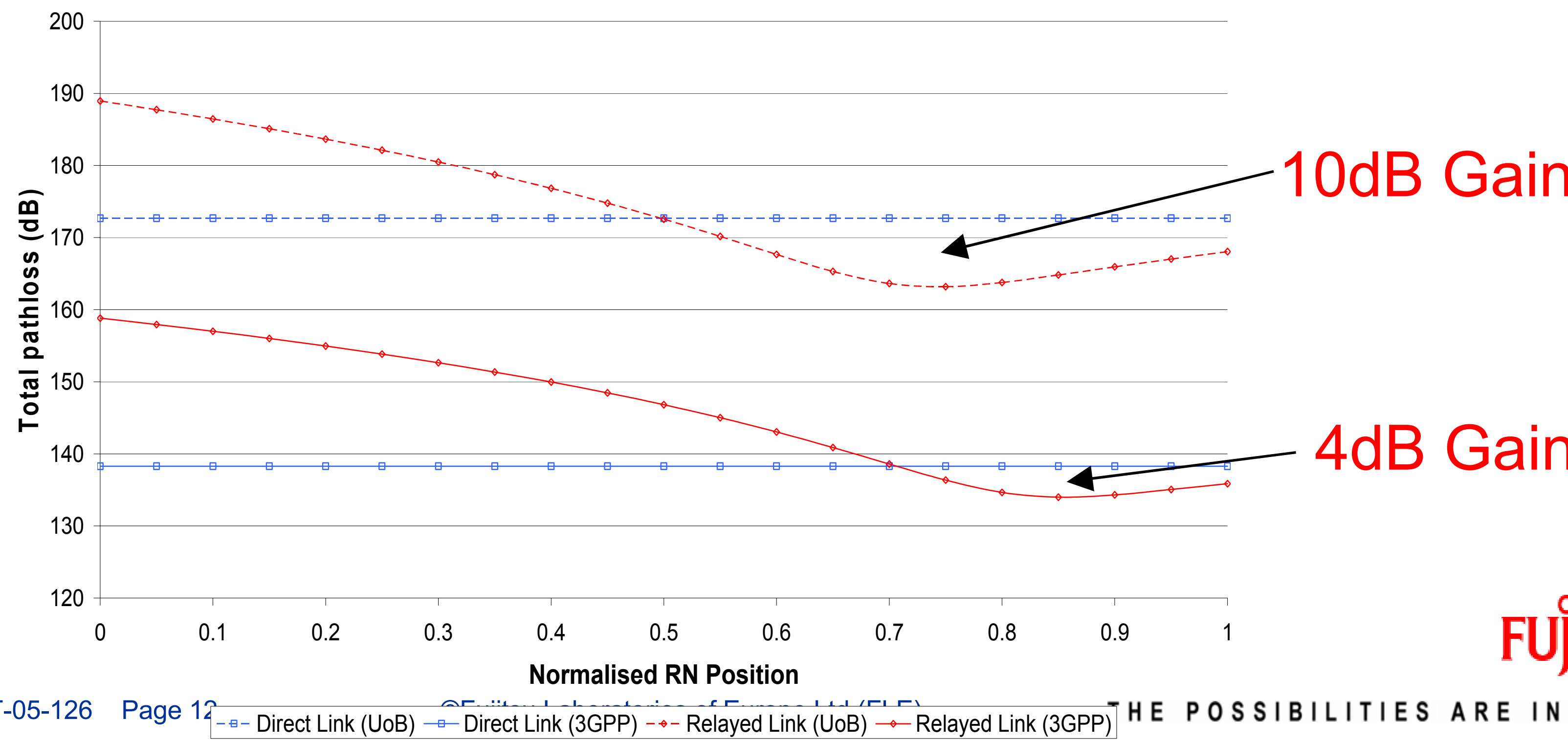
FUJITSU

THE POSSIBILITIES ARE INFINITE

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

FUJITSU

THE POSSIBILITIES ARE INFINITE

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:

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

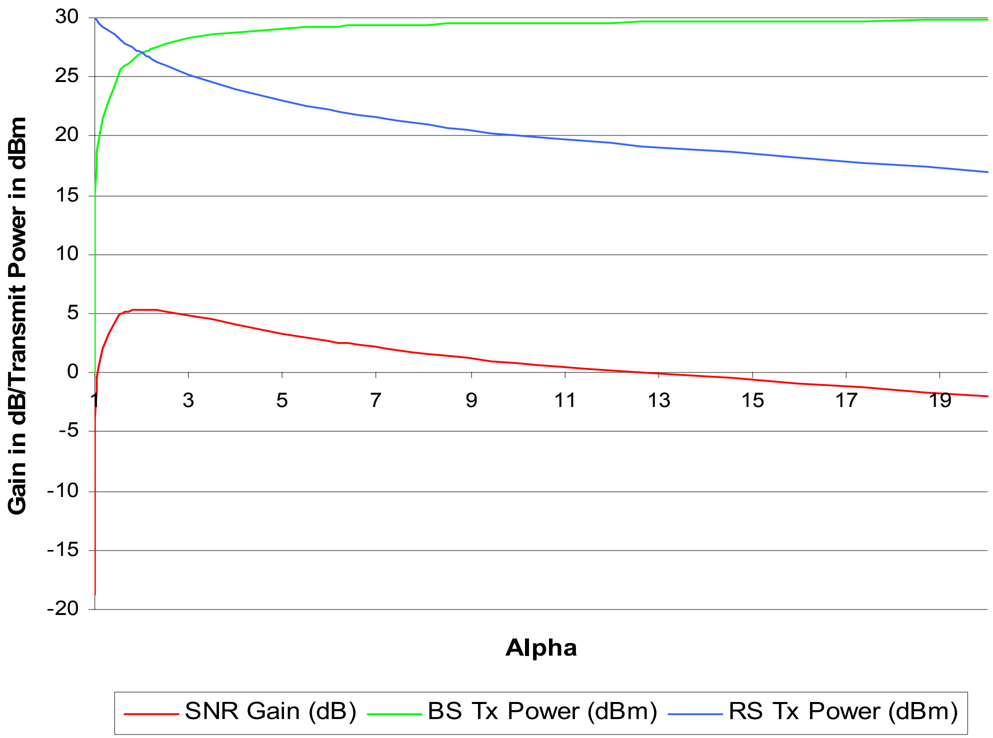
RS tx power

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:

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

- 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

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)?