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Performance Evaluation of Relaying Mechanisms in Wireless Networks

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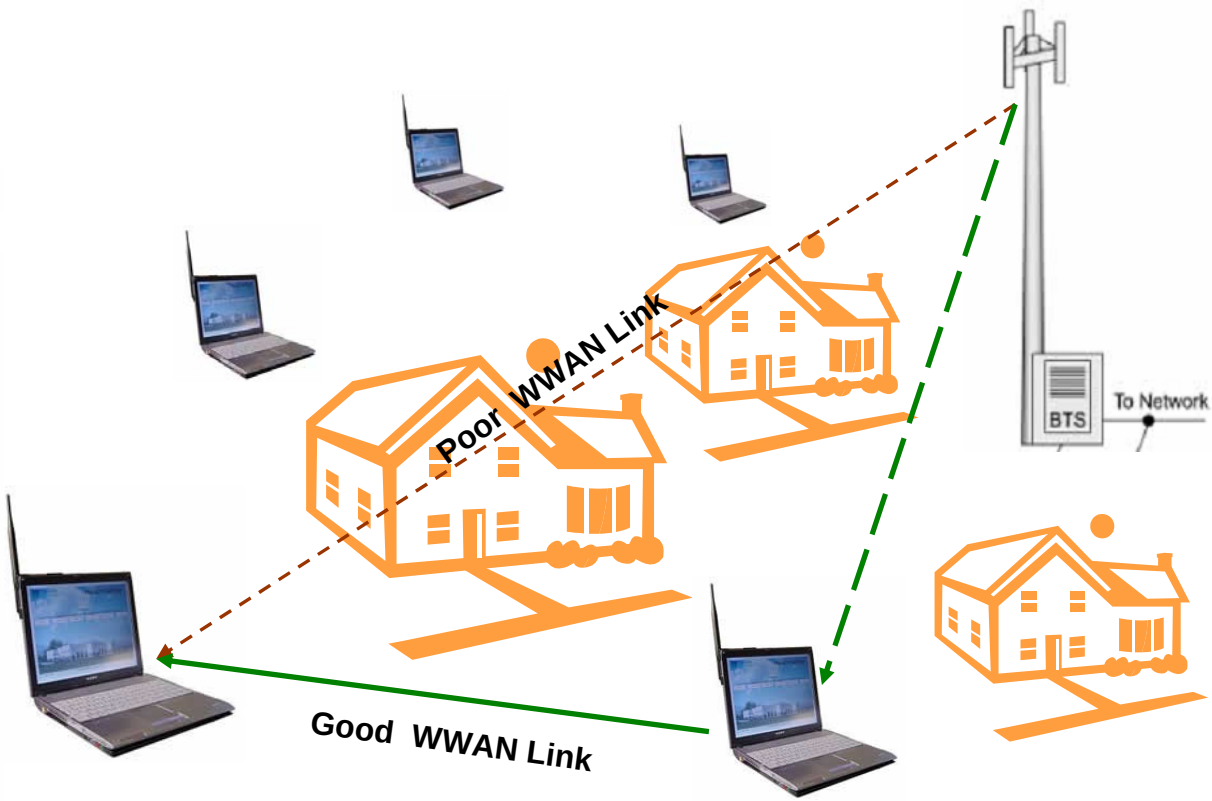
Outline

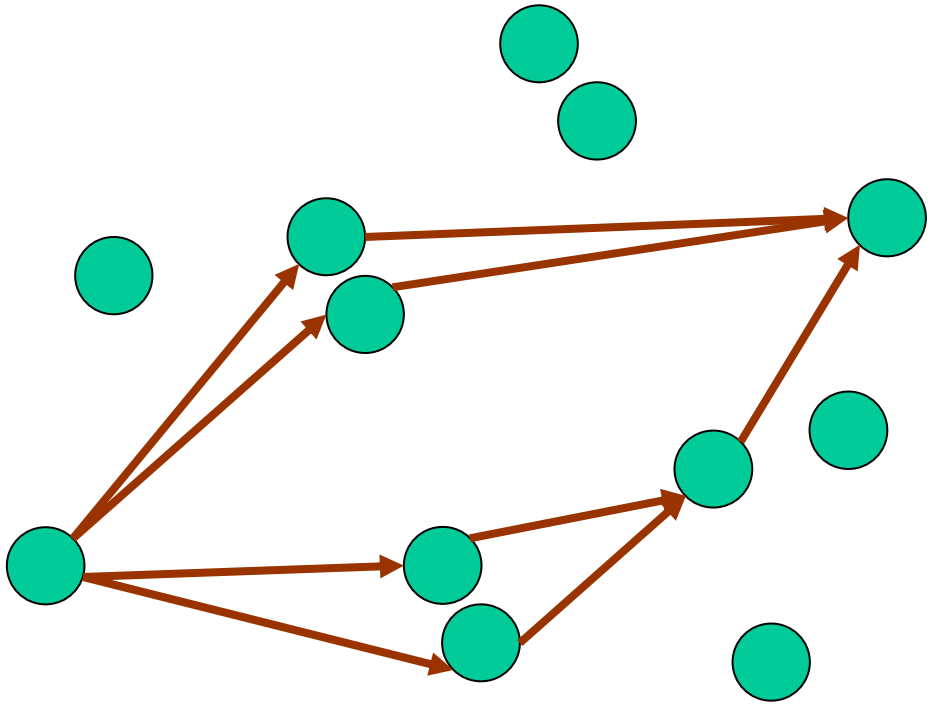
- Overview and motivation
- Relaying in wireless networks
- Simulation setup
- Simulation scenarios
- Link performance of the selected relaying algorithms for LOS and NLOS environments
- Conclusions

Application: WLAN and Cellular



Distributed relaying can be used to improve coverage – but also link quality and capacity.

Distributed / Cooperative Relaying

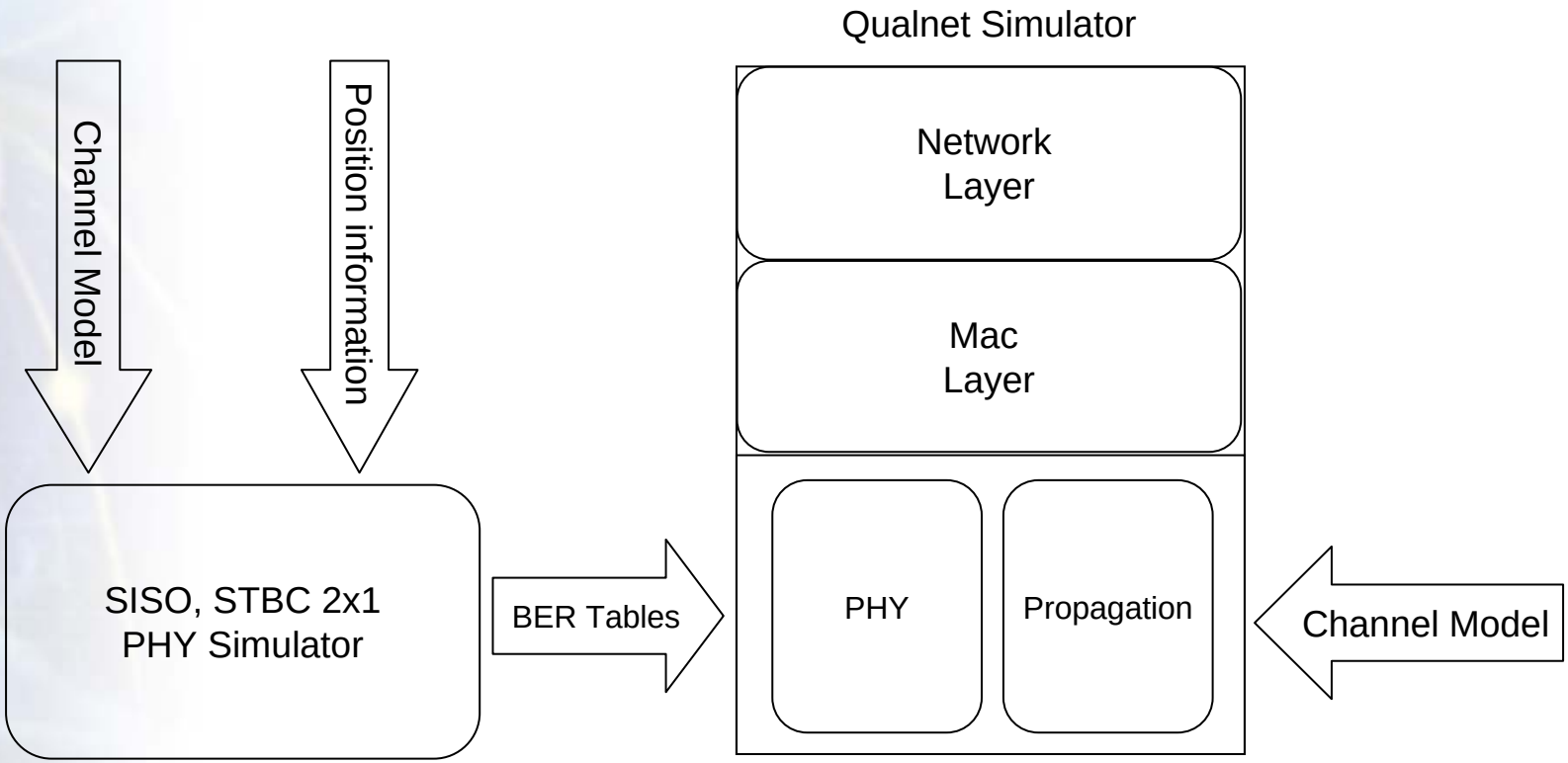


Idea → Nodes on the source-destination path can cooperate to create a “better” link.

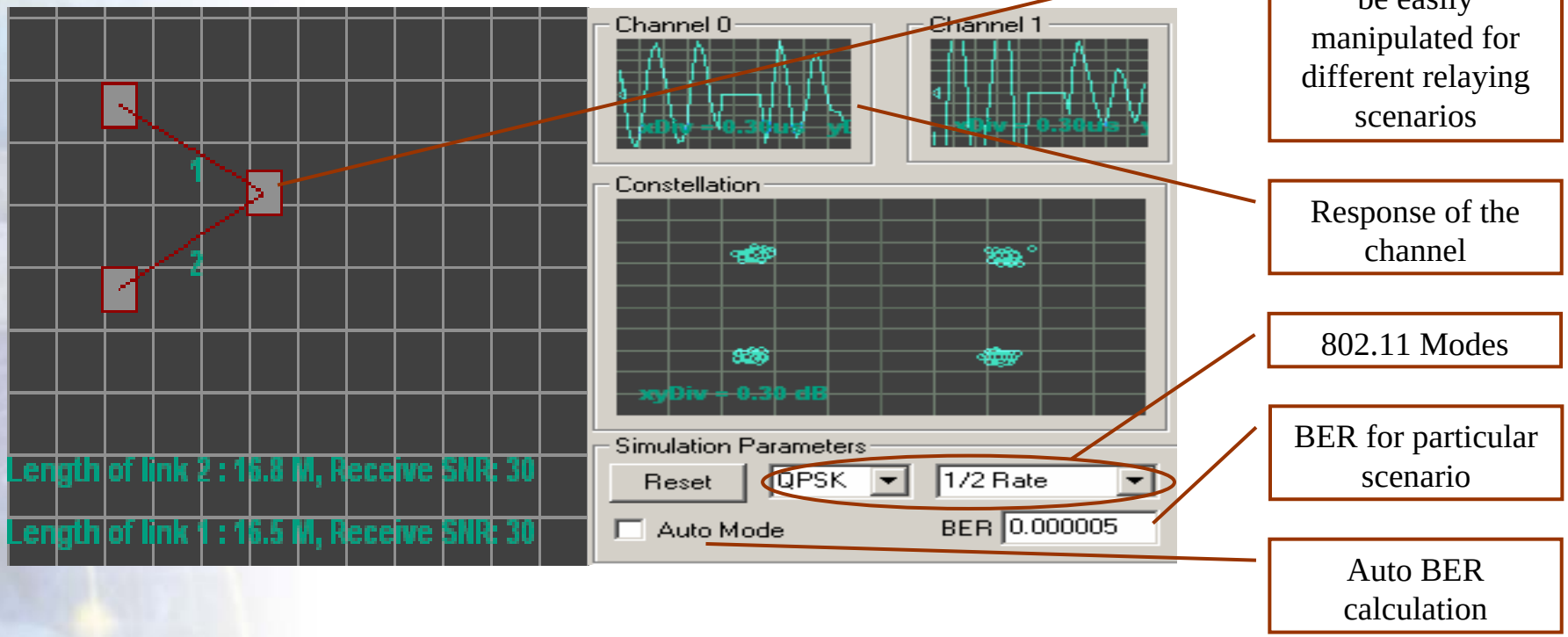
Main research question and Motivation

- How does relaying affect throughput of a communications system?
  - In terms of capacity
  - Coverage (already covered extensively)
  - Link quality
  - Interference and power consumption
  - Latency

Simulation Environment

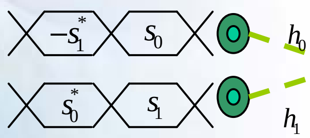


PHY Layer simulator



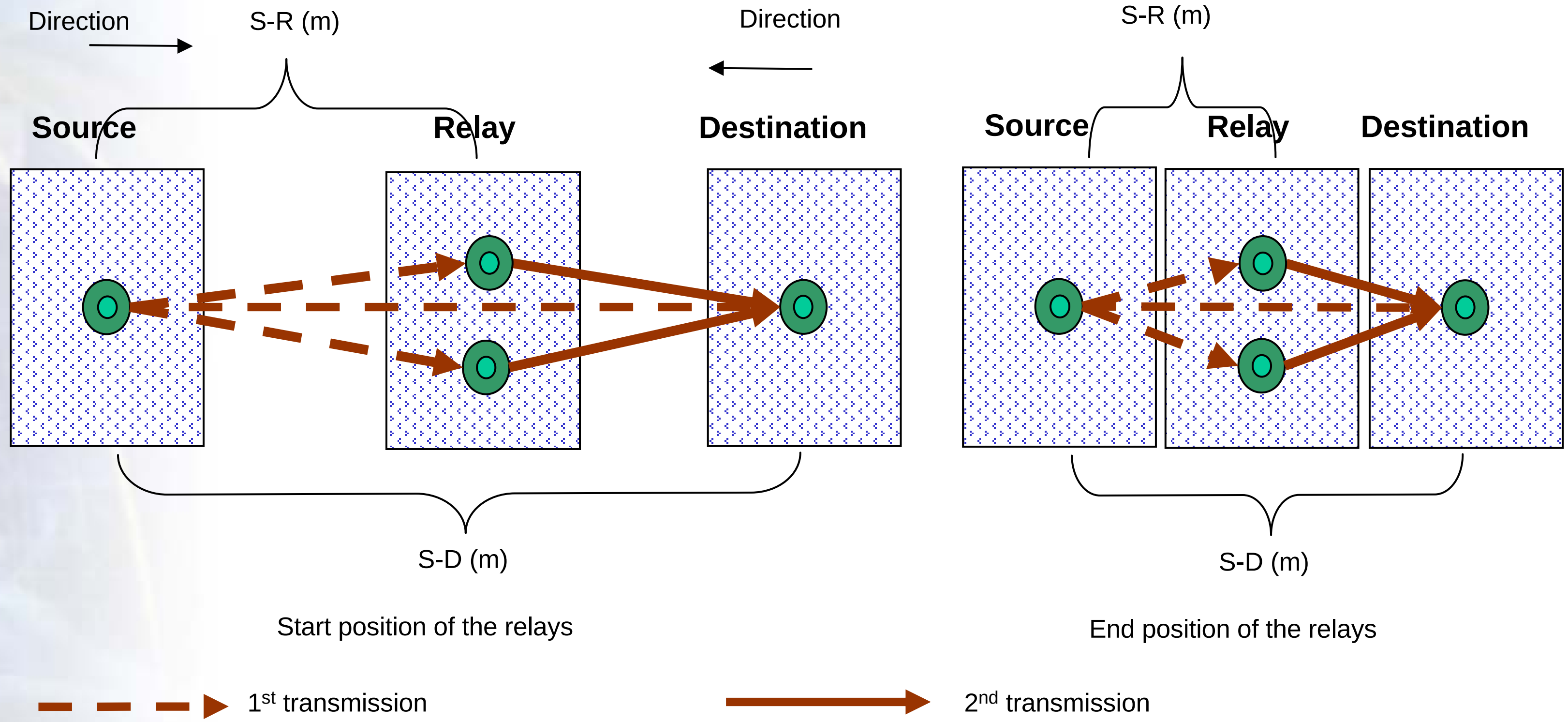
PHY layer simulator can produce BER information for both D&F, S-D&F, and STBC using AWGN and Channel Model A channel models, it also uses standard compliant constraint length seven Viterbi decoder with convolutional encoder.

Relaying Scenarios for Link Throughput



$$r_0 = h_0 s_0 + h_1 s_1 + n_0$$
$$r_1 = -h_0 s_1^* + h_1 s_0^* + n_1$$

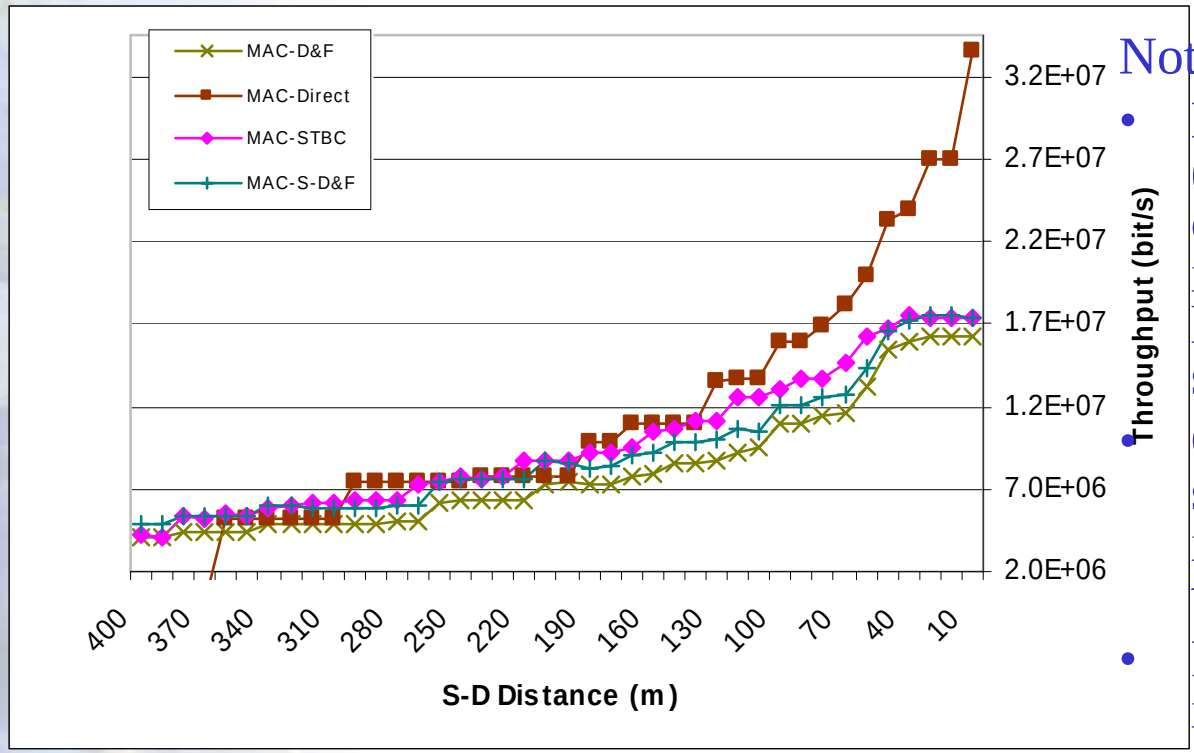
the error performance of the link



Simulation Parameters

- The nodes are placed in pre-determined locations and for each location a simulation is run for 60 seconds.
- In all simulation scenarios a constant bit rate (CBR) traffic with 1800 bytes packet length is used in order to investigate the maximum achievable throughput.
- The packet transmission interval at the application layer is chosen to be 800 microseconds.
- The node queues are assumed to be large enough that there is no packet drop.
- The CBR traffic generated by the application is chosen to be always greater than link throughput so there is no idle time in the wireless medium.

AWGN Results

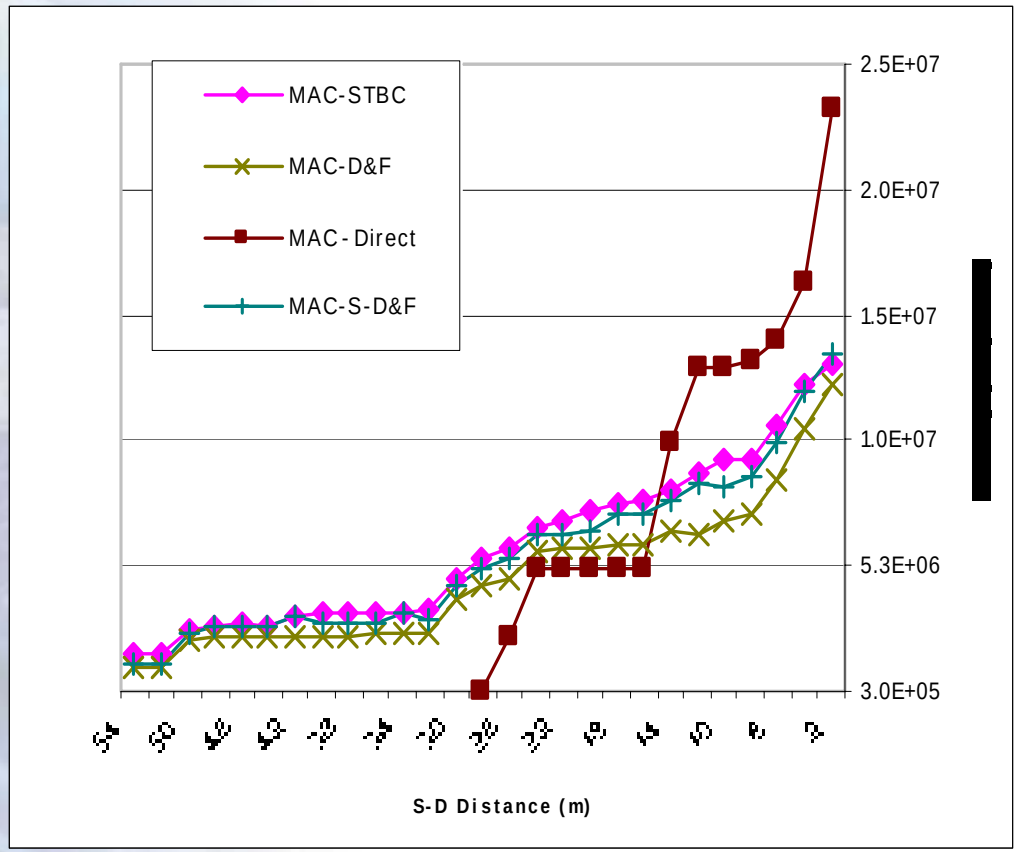


Notes from simulation results:

- Deploying relays (cooperative or non-cooperative) does not improve the capacity of the link considerably for LOS scenarios.
- Only coverage increase is significant since the signal is regenerated and transmitted by the relay.
- Path loss model for AWGN is:

$$L_p = 10\log_{10}(4\pi d/\lambda)^2$$

CHNLA Results



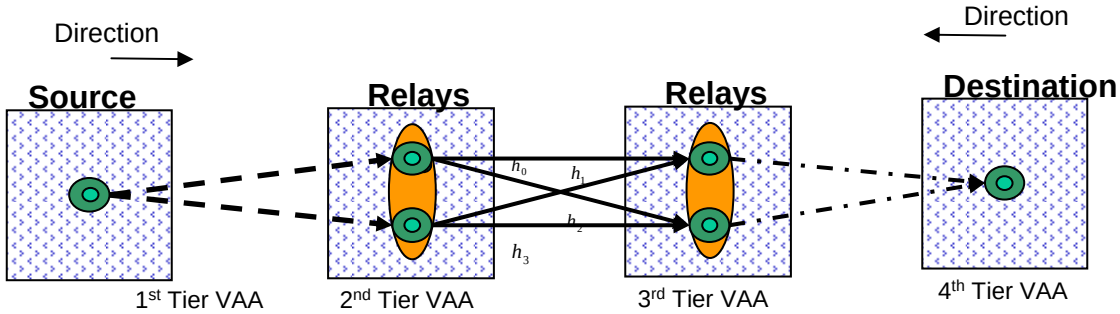
- All the evaluated relaying algorithms perform better with a Channel A model as compared to the AWGN channel with free space propagation. The main reason is the NLOS (non-line-of-sight) propagation environment in which the signal degrades very rapidly compared to LOS (line-of-sight) environments.
- Significant coverage increases can also be attained using relaying in NLOS environments.
- Path loss model for Channel Model A;

$$L_p = 10\log_{10}(4\pi d/\lambda)^2 + \alpha d$$

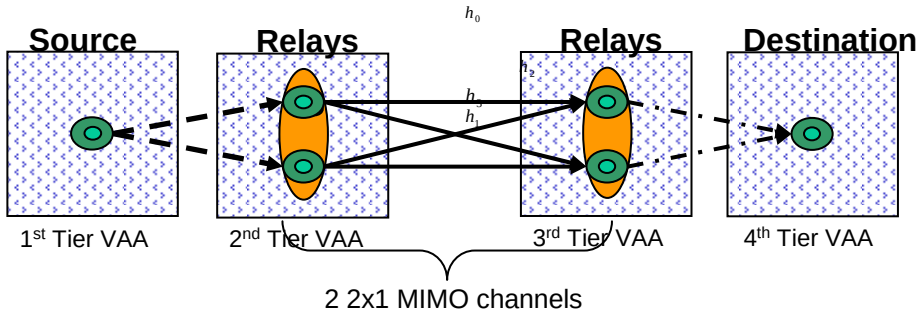
$$\alpha = 0.5$$

Multi-Stage D-STBC

Start position of the nodes

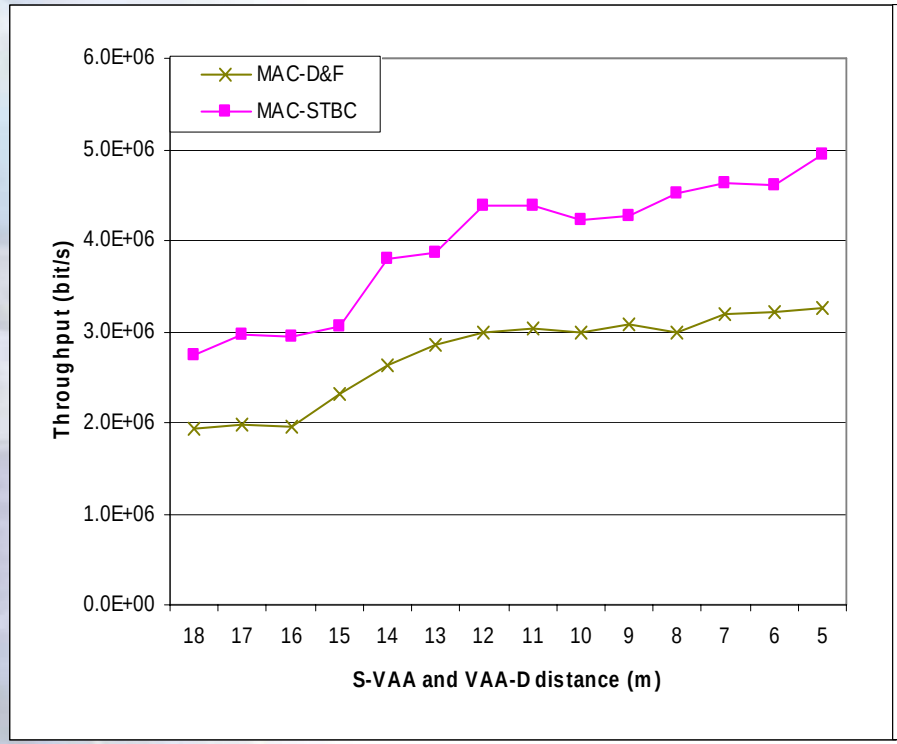


End position of the nodes

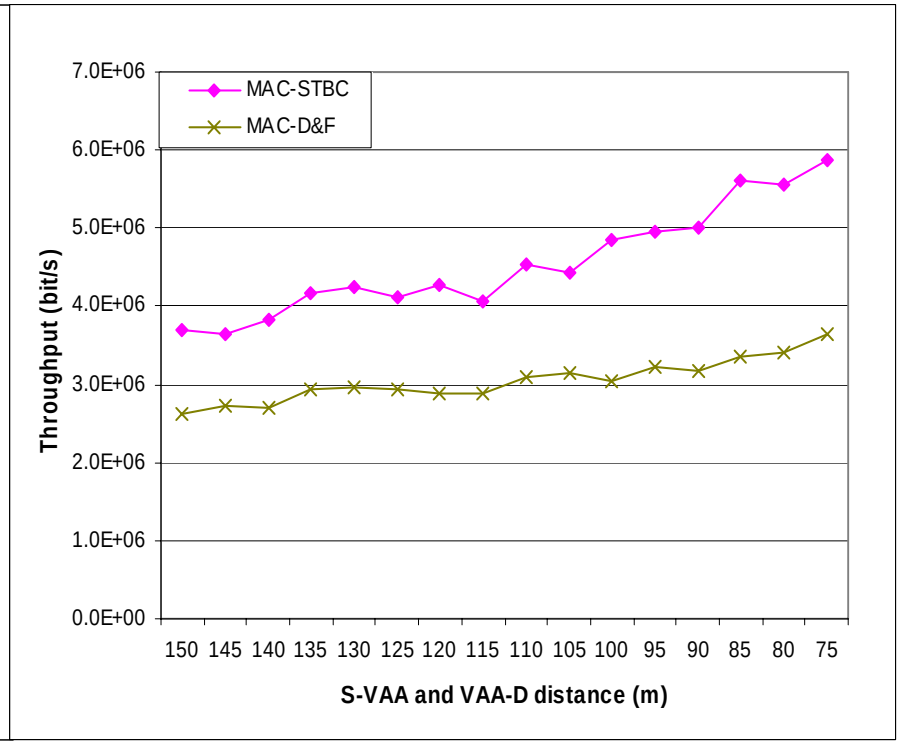


- If the packet travels over more than one relaying VAA, it is possible to form multistage relaying links.
- It is clear that the link between 2nd tier and 3rd tier VAA is a "MIMO-like" link and can support higher throughput compared to the source-2nd VAA and 3rd VAA-destination link.
- In our simulation the relays are fixed and the source and destination distance is decreased by a constant value for each run of the simulation.

Results for Multi-Stage D-STBC



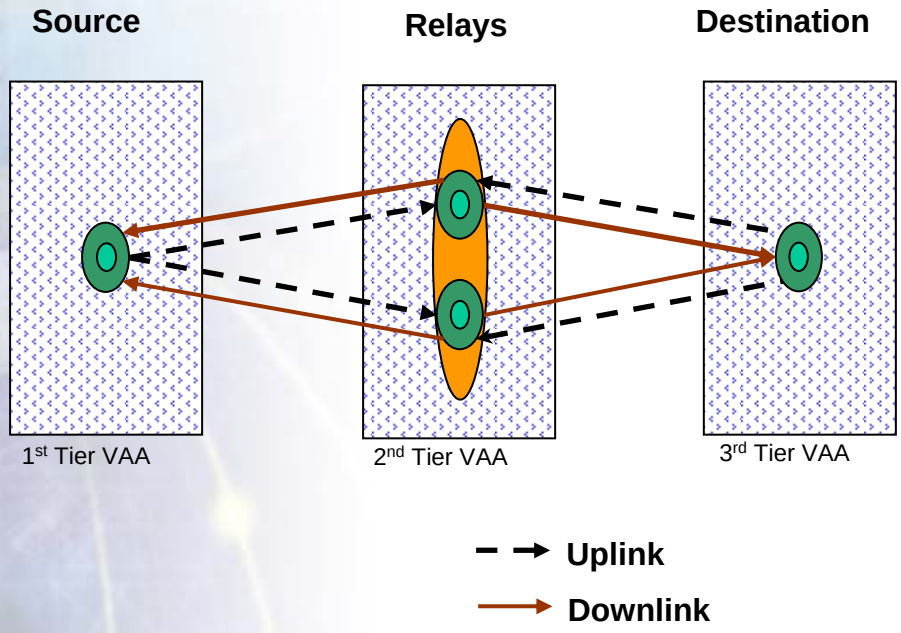
a) Channel A



b) AWGN

- For Multi Stage relaying deploying cooperative relays improves link throughput compared to non-cooperative relaying.
- The trend in the figure shows that Multi Stage relaying performs better in NLOS propagation environments.

Uplink and Downlink

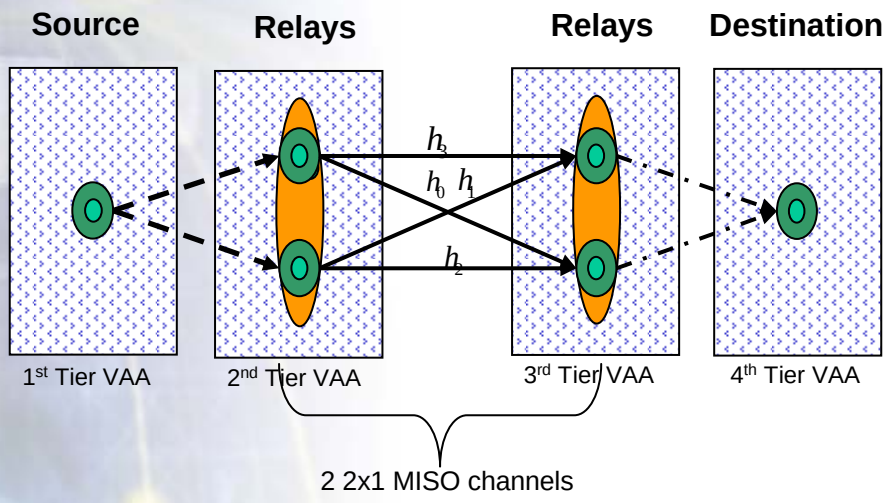


- If we ignore the transmission from the source, the achievable rate can be shown to be;

$$R_{DF} \le \max_{p(x1,x2)} \min\{I(X_1;Y_2 \mid X_2), I(X_2;Y_3)\}$$

- First term in the formula represents the rate at which the relay node(s) can decode the source message reliably, the second term represents the rate at which destination node can decode the retransmitted message from the relay.
- The maximum mutual information is always limited by the individual channel throughput between nodes.
- The main limiting factor for D-STBC cooperative systems is the difficulty of implementing coding on both uplink and downlink channels (non-reciprocal behaviour), since in 'Downlink' channel space time coding can be used but not in uplink channel, if inter-relay communication is not allowed.

Multi Stage D-STBC



- For multi stage D-STBC systems; the requirement of retransmission of the packet along the source-destination link, which will create delay in the link and drop the efficiency, is one of the limiting factors. The efficiency of the system in terms of transmission time can be given as;

$$E_{i,j} = \frac{\sum_{i,j} Td_{i,j}}{\sum_{i,j} (Td_{i,j} + Tack_{i,j} + Tifs_{i,j})}$$

- This is a draw back for multi-stage D-STBC systems since the source node needs to be close to the first stage VAA, and destination to the last stage VAA.

Conclusions

- For free space communication environment (no multi-path propagation), the proposed relaying methods provided almost no advantage over direct communication in terms of throughput increase. In multi-path fading environments all relaying schemas performed considerably well; D-STBC cooperative relaying was found to be the best candidate for these environments.

- Even though single stage D-STBC provided the best performance for two hop scenarios, the observed increase was quite significant compared to non-cooperative D&F method. But this difference is less impressive if one takes into account the complexity of the cooperative relaying methods (such as D-STBC and S-D&F).

- The multi-stage results show that D-STBC relaying provides better throughput than D&F relaying for scenarios where the transmitted packet travels thorough the same route for both relaying methods. The throughput increase is limited when the channel conditions between the source and the first stage VAA or the last stage VAA and destination is poor

Thank You and Questions ?