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Agenda item:

Source: Ericsson

Title: Comments on transmit diversity schemes with more than two antennas

Document for: Discussion

1 Background

TSG RAN has decided to include TX diversity with more than two antennas as a work item for R2000 (included as a part in the radio-link performance-enhancements work item).

RAN WG1 has done some first studies on such schemes, with concept proposals from Nokia, Samsung and Siemens.

This paper discusses the benefits/drawbacks of specifying new TX diversity schemes, and points to other alternative techniques.

In the following, the term HO-TX-DIV is used to denote the higher order TX diversity solutions.

2 Methods

There probably exists an almost infinitely number of different TX diversity schemes. The proposed solutions only make up a very limited subset of what can be conceived. Looking back at the TX diversity discussion for two antennas, a lot of concepts were reviewed on the way to the final concepts. Many of the methods will have very similar performance, but totally different algorithms. This is the same case as for the two branch TX diversity methods, where WG1 failed to arrive at one scheme, despite the fact that this would have been very beneficial from an operations, network, UE, and specification point-of-view.

Hence, in the given time frame it will be extremely difficult to agree on one single method for TX diversity with more than two antennas. Further, one may ask why the focus should be on four antennas, instead of e.g. three antennas, five antennas, or eight antennas? There is a lot of inflexibility built into the solution selected, which leads to benefits for some site configurations, and no benefit for others. That is of course true also for the two branch TX diversity schemes, but there one may argue that the use of two antennas for reception is the common way to build a site. This also indicates two antennas to be the most natural extension for transmission.

More general feedback signalling schemes would seem to be preferred, where the UE provides e.g. phase measurements that can be filtered and used by Node B in any way it wants. However, it seems difficult to agree on quantization and frequency of the signalling, without having particular Node B algorithms in mind. Further, specifying performance requirements could be difficult for this case.

3 Performance

The presented schemes show similar performance behaviour, good performance at low speed and bad performance at higher speed. One effect not considered so far is the negative impact that comes from the need of four CPICH signals instead of one (or two). This needs to be taken into account.

If performance is as good as is indicated in simulations, surely there will be code limitation problems. This can be avoided by the use of secondary scrambling codes, but that will obviously reduce the expected system gain.

4 Complexity

One big drawback of the proposed schemes is the impact on the UE implementation complexity. If the methods rely on channel estimation from CPICH signals from each antenna, there will be additional complexity introduced by these channel estimators. Further, calculation of feedback signalling is needed as well which also contributes to an increased UE complexity.

Since any TX diversity scheme specified will need to be mandatory for all UEs (otherwise it is difficult to see the incentive for a UE manufacturer to implement it), this additional complexity will impact UEs of Release 2000 or later. One may question if this additional UE complexity in all terminals is justified by the potential capacity gains in cells using HO-TX-DIV. It seems reasonable to assume that a minority of cells will be equipped with HO-TX-DIV hardware.

5 Backwards compatibility issues

Backward compatibility issues need to be addressed for HO-TX-DIV methods. In order not to decrease the performance for R99 mobiles, CPICH powers for antennas 1 and 2 must be the same for the case with e.g. four antennas, otherwise coverage loss may result for the old mobiles. Hence, if CPICH power is needed on antennas 3 and 4, this will always be additional power, the total power cannot be kept and just split over more antennas.

Further, backwards compatibility makes improvements of common channels such as PICH, AICH, P-CCPCH etc unattractive, since the old channels needs to be kept for R99 UEs.

6 Alternative techniques

Adaptive antenna (AA) systems are obvious alternatives to HO-TX-DIV systems. In AA systems, antenna arrays (linear or non-linear) are used together with beamforming means to improve SIR in both uplink and downlink.

A major part of the additional hardware cost of a HO-TX-DIV system lies in the additional radio chains, with additional PAs, feeder cables, and antenna elements. Exactly that part is probably the big additional cost for an AA system as well. Hence, one should consider if the cost in radio chains are not better used by using AA algorithms instead. Such algorithms bring additional benefits. For example, some algorithms use spatial correlation properties to avoid strong interferers. This will lead to additional chances of performance gains for inhomogeneous traffic sources and traffic distribution.

Code limitation problems can be avoided through the use of secondary scrambling codes. However, contrary to the HO-TX-DIV methods, the spatial domain can be used to avoid increased interference due to non-orthogonality between code sets. Hence, an AA system will see a smaller negative impact of the use of secondary scrambling codes.

Furthermore, HO-TX-DIV systems only bring performance benefits to low mobility users, and could potentially cause harm to high-speed mobiles. This is not true with AA systems, which are capable of bringing benefits to all users, independent of the channel models and mobile speeds. There may be some variations in the performance for different algorithms, but there are significant gains to be found for all users.

In addition to all the benefits mentioned above, AA systems have one major benefit: they do not require any standardisation. It is true that to utilise some benefits with AA systems, additional signalling is needed between Node B and RNC. However, in many cases this can be solved by proprietary signalling, for which the Iub protocols are prepared. Also, if the AA system is not used to the limit, there are solutions where the impact can be kept within Node B.

For an AA system to operate additional antennas are needed also in uplink. However, this seems to be a very small cost of the whole package. Moreover, this is not just additional hardware, it also brings benefits in terms of coverage, capacity and quality for the uplink.

7 Conclusion

There will be some performance gains with higher order TX diversity schemes. However, using similar amounts of hardware, other solutions without any standardisation impact, and with better or even much better performance can be obtained for larger variations of environments and mobile speeds.

Hence, taking into account the additional complexity in all mobiles and that the use of the scheme on the network side probably will be limited, it seems that standardising one or several additional TX diversity schemes is quite unattractive.

As a conclusion, we recommend RAN WG1 and TSG RAN to not continue work on this work item, and thus not include any new TX diversity schemes into release 2000 specifications.