MIMO in HSPA: the Real-World Impact

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1 Executive Summary

This paper is designed to provide a neutral and balanced view of MIMO (*Multiple Input Multiple Output*) technology and its role in the evolution of mobile networks, while exploring concerns raised by some industry players and telecoms operators about the use of MIMO with HSPA.

In the past few years, operators have seen huge growth in mobile internet usage. To cope with this growth, mobile operators are increasing the capacity of their networks, either by acquiring new spectrum, refarming existing spectrum, and/or by relying on advanced technologies to increase efficiency of spectrum utilization.

Even in cases where new spectrum is available, acquiring new licenses and building out entirely new networks can involve considerable CAPEX. A potentially quicker and less expensive option can be to adopt new technologies, such as higher order modulation (HOM) or MIMO, or to deploy devices with improved receiver performance.

Whereas all such approaches have merits, and indeed are complementary in nature, commercial deployments of MIMO have demonstrated that the technology is a very effective way to improve the system and individual users' data capacity, without additional bandwidth, and to ensure a higher guaranteed bit rate, across large coverage areas, right up to the cell edge. In fact, MIMO is now established as a key feature of both HSPA and LTE technologies.

In particular, commercial deployments of MIMO have demonstrated:

- An average cell throughput gain of 20% or more compared to single Tx antenna solutions, and individual user throughput gains of 35% or more.
- MIMO products have reached maturity and are offered by the majority of mobile equipment vendors, making MIMO a cost-effective solution. The most recent MIMO-ready NodeB solutions add only a small fraction to the total site costs. On the chipset side, MIMO costs are falling, enabling the technology to propagate from the high-tier to the mid-tier segment. Devices are also increasingly equipped with dual-antenna configuration to support receive diversity and/or LTE MIMO, and such configurations can be leveraged for MIMO HSPA devices without adding to the RF bill of materials.
- Effective network-based solutions (VAM, PSP, Common Pre-coder power balancing, etc.) enable the co-existence of MIMO and legacy HSDPA terminals and avoid any measurable performance impact on the latter.
- MIMO is playing a key role in both the evolution of HSPA and LTE. It is backed by the main equipment industry players who have already mapped 3GPP R9, R10 MIMO related features into their development plans.

2 The Role of MIMO in HSPA

Demand for mobile data services is growing in epic proportions. Faced with this growth, mobile operators are looking for opportunities to cost-effectively increase capacity. MIMO is one of the powerful tools in their arsenal, as it can significantly improves data rates, user experience and capacity within existing spectrum and through an upgrade to existing infrastructure.

MIMO, along with Beamforming/Transmit Diversity and others, is one of a slew of advanced antenna techniques in the HSPA evolution roadmap. MIMO, in particular, plays a central role in delivering the successively higher peak data rates in each iteration of HSPA+, from 28 Mbps in Rel. 7 to 168 Mbps in Rel. 10 and even higher in Rel. 11 and beyond, also called as *HSPA+ Advanced*.

2.1 What is MIMO, and What Does it Provide?

MIMO, as the name suggests, involves leveraging multiple transmit and receive antennas available at the radio base station and the device to increase data rates, overall capacity and the user experience. Essentially, the MIMO *system* uses the antennas and "processing" at both transmitter and receiver to create multiple uncorrelated (having different fading characteristics) radio links (called: 'streams') between the transmitter and receiver. These streams use the same time and frequency resources, enabling capacity to be increased without an increase in spectrum.

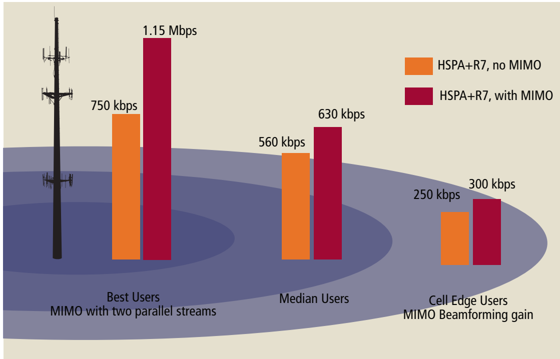
To sum it up, an increase in antennas allows for more streams between them, enabling more information to be transferred and a higher data rate. All of this, while using the same amount of spectrum and transmit power. Every order of MIMO doubles the peak rates, for example, HSPA Rel.7 2x2 MIMO doubles the peak rate over the same system with 1x1 antenna configuration.

MIMO is most effective when uncorrelated streams are created, which typically happens when a device has good coverage, but no line of sight (LoS) to the base station. This is generally the case in urban environments, which in most instances, is where the higher capacity is desired.

MIMO improves data rates for all users and increases capacity

Figure 2.1 illustrates the benefits of 2x2 MIMO for an HSPA Rel. 7 network.

Figure 2.1: MIMO Improves Data Rates for all Users and Increases Capacity



Source: Qualcomm Simulation. NGMN D1 500m ISD with 10 users per cell. MMSE Equalizer. Shows data throughput for the median, 10% best and the 5% worst (cell edge) users.

As the above graphic illustrates, all the users in a cell can benefit from MIMO. Users close to the cell centre, being in better coverage, benefit from MIMO due to special multiplexing gain, which is achieved by transmission of two parallel streams; whereas users near the cell-edge benefit from another manifestation of MIMO, called Beamforming, which is achieved by dynamically switching to single stream transmission on the two transmit antennas, when radio conditions deteriorate.

The sum effect of MIMO is that it provides at least a 20% increase in the overall capacity of the network.

3 Implementation and Deployment

3.1 Co-existence of MIMO and Legacy Terminals

Undoubtedly the main deployment challenge, as witnessed in the initial roll outs of MIMO networks, is to ensure that MIMO can co-exist with legacy (i.e., pre-Rel-7) HSPA terminals. This co-existence challenge dates back to 2007 when early HSPA terminals with advanced receivers were first deployed.

An HSPA terminal can be categorized by the performance level of its receiver(s). 3GPP TS25.101 specifies the minimum throughput performance for both and advanced receiver architecture.

However, the specified performance requirements are derived from the following assumptions:

- The ‘basic’ HSDPA receiver is based on the standard RAKE receiver used with the W-CDMA radio interface.
- The ‘Type2’ receiver is based on a linear equalizer, which improves performance, especially when multiple paths are used by the radio signals travelling between the base station and the device.
- The ‘Type3’ receiver supports dual-antenna reception, together with equalization on each branch.

  The ‘Type3i’ receiver supports multiple antennas, with an advanced equalizer, and is capable of partly suppressing the interference caused by other users in the serving cell or adjacent cells.

Devices equipped with advanced receivers of Type2, Type3 and Type3i have all been rolled out commercially. However, some commercial devices have been equipped with an equalizer that will fall back to the lower performance RAKE receiver functionality, if the serving cell is in STTD (Space Time Transmit Diversity) mode.

MIMO can be operated in one of two modes. In STTD mode, the base station transmits primary CPICH (P-CPICH) and diversity CPICH, while, in Primary-Secondary-Pilot (PSP) mode, the base station transmits in both primary and secondary CPICH (S-CPICH).

In theory, STTD mode provides the largest capacity gain, since both MIMO users and non-MIMO users can benefit from transmit diversity. However, this mode will result in a net degradation of performance when a large proportion of user devices have equalizers that fall back to RAKE receiver functionality in STTD mode. In such circumstances, the PSP mode is preferable.

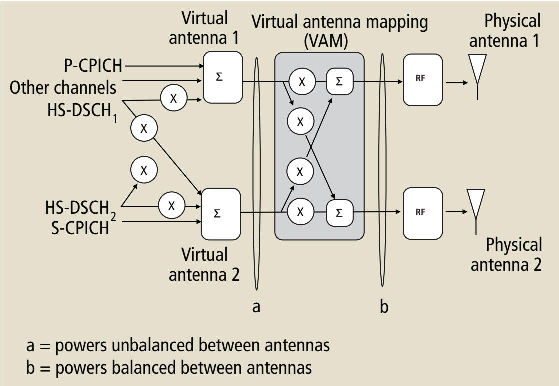
However, when PSP mode is used for MIMO, the base station needs to be provisioned with certain capabilities to achieve optimal performance. These capabilities are Virtual Antenna Mapping (VAM), PCI codebook restrictions, and unequal setting of P-CPICH and S-CPICH transmit power. Each of these is described below.

3.1.1 Virtual Antenna Mapping with PCI Code Book Restrictions

When the base stations transmit in S-CPICH, the transmit power of the two antennas may differ, which can lead to the non-optimum use of power amplifier (PA) resources. To overcome this problem, Virtual Antenna Mapping, or Common Pre-coder power balancing, is used.

VAM introduces a power balancing network to enable base stations with P-CPICH and S-CPICH to fully exploit the power of the two PAs when transmitting to non-MIMO devices. (See Figure 3.1).

Figure 3.1: Virtual Antenna Mapping



The use of VAM has no impact on legacy devices' performance. However, in the case of single-stream MIMO transmission, the use of VAM may result in some PA power imbalance and hence PCI restrictions need to be in place as described in a CR to TS25.214, documented in R1-100729. Note, restricting the PCI code book has a small effect on the beamforming gain obtainable with single stream MIMO.

3.1.2 Unequal Setting of P-CPICH and S-CPICH Transmit Power

Further optimization of the VAM, or Common Pre-coder power balancing solution, is possible by transmitting the P-CPICH and the S-CPICH at different power levels.

The power allocated to the S-CPICH consumes downlink capacity that could otherwise be allocated to downlink channels carrying user data. Moreover, the S-CPICH also contributes to the overall interference seen by the non-MIMO terminals.

Transmitting the S-CPICH at a lower power than the P-CPICH can drastically decrease its impact on the base station transmit power budget, without any measurable impact on the performance of MIMO devices.

Tests by Ericsson in different radio conditions, in combination with its Common Pre-coder for power balancing, found that the user experience is maintained even when S-CPICH power is set down to -3dB. To further reduce the impact for non-MIMO devices, Ericsson suggests that S-CPICH is only transmitted in the cells where MIMO terminals are present.

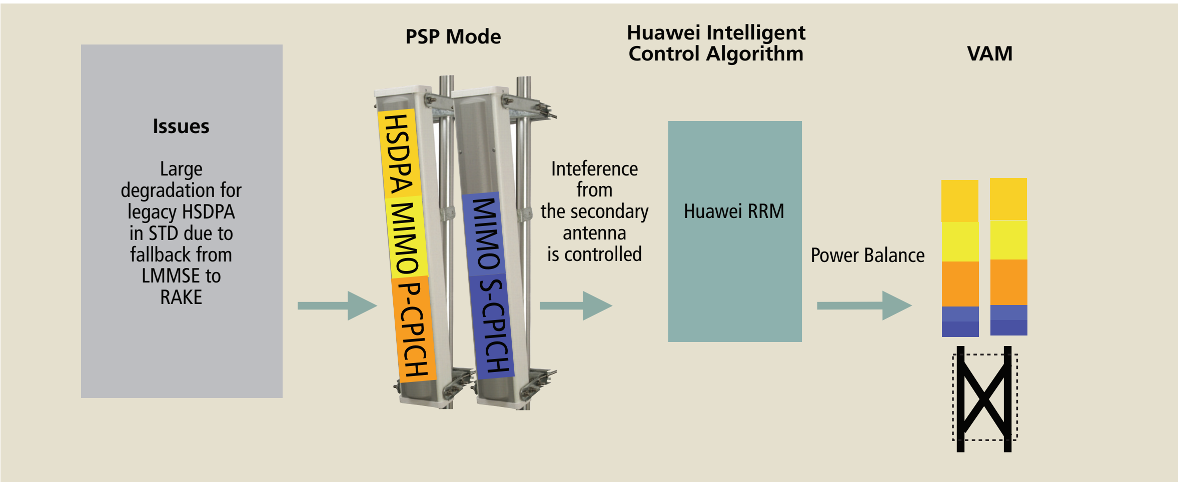
Transmit power inbalance between the P-CPICH and the S-CPICH needs to be signaled by the base station to the MIMO devices to ensure optimal demodulation. The need for such signaling capability is captured in two CRs to TS25.214 and TS25.331, as described in 3GPP documents R1-093631 and RP-090840.

3.2 An Implementation Example

In order to implement the capabilities described above, some infrastructure vendors have developed a mix of standards-based (3GPP) and proprietary network-based algorithms. These techniques are implemented in the base station and they do not pose any requirements or dependencies to standard end-user devices.

To develop a MIMO co-carrier solution, Huawei Technologies, for example, used a new interference cancellation technique, along with a Virtual Antenna Mapping (VAM) solution, to reduce the interference caused by the secondary antenna and reduce the loss in legacy HSDPA throughput. Figure 3.2 shows the functional blocks of the Huawei's MIMO & legacy HSDPA coexistence solution.

Figure 3.2: Overview of Huawei Co-Carrier Solution for MIMO & Legacy Terminals



Intelligent Control Algorithm
The Intelligent Control Algorithm is a special interference cancellation technique designed by Huawei and used as a part of Radio Resource Management (RRM).

When the PSP mode is used, the signals transmitted through the secondary antenna are unknown to a legacy HSDPA device. Therefore, the receiver of the legacy HSDPA device does not suppress the multipath interference caused by these signals. As a result, the performance of legacy HSDPA services degrades. The Intelligent Control Algorithm smartly monitors the proportion of various users in a cell and dynamically allocates the total available power to MIMO users and HSDPA users. In this manner, the RRM controls the interference of the signals transmitted through the secondary antenna on the HSDPA signals, without deteriorating the HSDPA performance.

According to field trials experience, the performance loss for cat-8 (type-3 receiver) is substantially reduced as compared to previous solutions. The average loss of HSDPA legacy devices is fully eliminated in a MIMO cell, and still maintains a huge gain for the MIMO users.

As shown in the illustrations below, through the optimized MIMO solution, the overall average cell throughput gain compared to single TRX solution is more than 20% and the single MIMO users' throughput gain is more than 35%.

Figure 3.3: MIMO User Throughput Gain in Huawei Solution

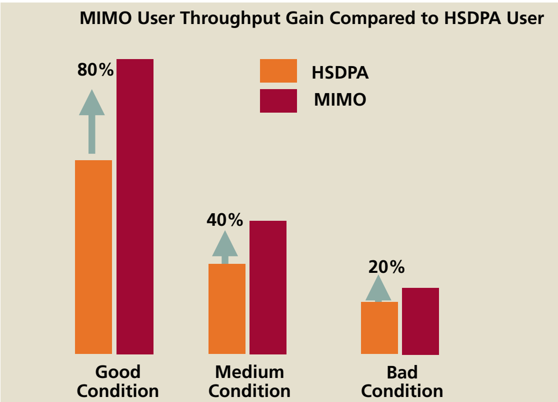
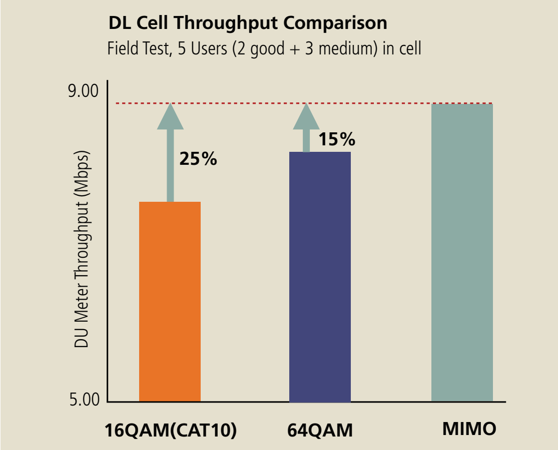


Figure 3.4: MIMO Cell Throughput Gain in Huawei Solution



3.2.1 Putting it all Together: the Solution for MIMO Co-existence with Legacy Devices

To summarize:

- Using P/S-CPICH for MIMO, as their receivers can use the equalizer functionality and do not fall back to RAKE functionality.
- Using P/S-CPICH with VAM or Common Pre-coder power balancing, base stations can fully exploit the power of the two PAs when transmitting to non-MIMO devices, as well as MIMO devices.
- VAM or Common Pre-coder power balancing itself has no impact on the performance of the non-MIMO devices. VAM imposes restrictions to the code-book used by MIMO devices and hence has a small impact on the MIMO beamforming gain in single stream mode.
- P/S-CPICH MIMO is further optimized by setting S-CPICH power lower than that of the P-CPICH in order to alleviate the burden on the base station's transmit power budget.

Table 3.1 and Table 3.2 summarize results of lab testing of the MIMO solution for co-existence with legacy devices. P-CPICH and S-CPICH transmit power levels are set to 10% and 5% of maximum cell power, respectively. Channel model is PA3.

Table 3.1: MAC Layer Throughout Performance (bps) of Legacy Devices when Co-existing with MIMO Devices

Cell Geometry (dB)	Legacy Cat.8 Device	Legacy Cat.8 Device in the Presence of P/S-CPICH & VAM
0	1645	1655
5 dB	2963	2932
10 dB	4398	4291
15 dB	5710	5536

Table 3.2: MAC Layer Throughput MIMO Performance (bps) with VAM and PCI Codebook Restrictions

Cell Geometry (dB)	Cat.16 Device in a non-MIMO Cell	Cat.16 Device in a MIMO Cell with P/S-CPICH and VAM w/ PCI Codebook Restrictions
0	2480	2905
5 dB	4621	5368
10 dB	7521	8632
15 dB	9898	12161
20 dB	11651	15311

In summary, co-existence solutions are now available that have virtually no impact on legacy devices, and to a large extent, retain the gains made possible by MIMO. The removal of this roadblock, paves the way for the extensive roll-out of MIMO technology in HSPA networks.

3.3 Deployment Considerations

Theoretically, MIMO can be deployed anywhere HSPA services are offered, such as densely-populated urban areas, suburban, and rural areas. Nevertheless, this technology brings the most benefit in urban and dense urban areas which typically the case in an urban area. In such scenarios, there is normally:

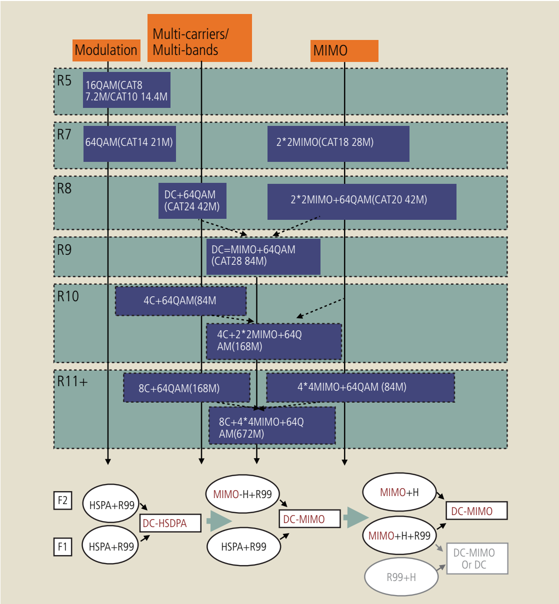
- A short distance between sites,
- A comparatively high Signal-to-Noise Ratio (SNR),
- Path diversification and rich scattering,
- Relatively slow movement of end-user devices.

Based on the number of available UMTS carriers, telecom operators adopt different service allocation strategies to exploit their spectrum assets in the most efficient way possible.

In the case of one 5MHz carrier only, MIMO can be used to reach 28Mbps or, when combined with HOM (64QAM), to reach 42Mbps.

Operators with multiple, adjacent 5MHz carriers might first choose to implement Dual-Carrier HSPA (DC-HSPA), which allows peak speeds of 42Mbps. Although DC-HSPA is less spectrum efficient than MIMO, it gives better cell-edge performance than single-carrier MIMO. Operators with enough available spectrum might choose to improve cell-edge performance first, before adding MIMO to increase spectrum efficiency when data traffic in their networks rises further, increasing the peak speed to 84Mbps (see Figure 3.5).

Figure 3.5: Different Evolution Strategies, where MIMO Plays a Fundamental Role



As mentioned earlier, MIMO requires two transmit channels. The power setting of the two Power Amplifiers (PAs) for transmit channels has a significant impact on MIMO performance. When deploying MIMO on the existing network, operators are advised to keep the total transmit power of a carrier unchanged to avoid affecting the overall network quality in urban areas. For example, if the transmit power of a carrier is 20 watts before MIMO, after MIMO deployment the total transmit power will still be 20 watts, but split into two 10 watt channels. By doing so, the cell coverage is not impacted. Moreover, no additional EMC permits are needed. In the cases of rural networks or newly-built networks, operators may even consider using higher power settings in the two transmit channels, such as 20+20 Watts, to ensure broader coverage from the outset.

3.3.1 MIMO Upgrade: Investment and Costs

Implementing MIMO is more affordable today for operators than perceptions of earlier implementations might suggest. Here are the key cost considerations for operators considering introducing MIMO:

Antenna system: Most telecom operators use mainly dual-polarized antennas, or anyhow have two antenna arrays for the Rx diversity of the Uplink. These antenna configurations and the relevant RF feeders do not need to be transformed to support MIMO. This cost is therefore zero.

RF system and radio modules: What concerns telecom operators most is the possible impact on the RF modules in the base stations. Many RF deployed modules in existing networks support only one transmit channel, so such RF modules must be duplicated and interconnected to support MIMO. According to industry benchmarks, the expense of this operation would account to up to 40% of the cost of the whole base station.

On the other hand, since 2009 many mainstream vendors have introduced new generations of RF modules which are **MIMO ready**, in that they have two transmit chains inside. With such modules, which are already common in many operators' networks today, only a simple software upgrade is required without any need for either hardware or cable modification. Compared with legacy RF modules supporting only one transmit channel, MIMO-ready RF modules normally cost up to 30% more. This means a delta cost at base station level of only up to 10%, if compared to the legacy solutions.

More broadly, deploying the new generation of RF modules, enables operators to best exploit their spectrum resources, and use simple software upgrades to make the long-term evolution steps of HSPA and LTE, which always requires MIMO in combination with other features. (see below).

User devices: Currently most, if not all, HSPA devices in the form of USB dongles or WiFi routers come equipped with two antennas and with a receiver capable of receive diversity for improved performance. Such dual-antenna systems, together with all relevant RF front-end components (switches, filters), can be entirely reused for MIMO applications. That is, MIMO has no impact on the RF bill of material (BoM) of the device.

The trend of using a dual-antenna system can now be clearly seen also in handheld devices and tablets, in part due to the introduction of multi-mode HSPA/LTE devices. Whereas MIMO is an optional, albeit important, capability, in HSPA devices, MIMO is mandatory in LTE devices. Hence one can expect dual-antenna devices to become mainstream in the near future. Moreover, MIMO is now supported in mid-tier chipsets, as well as high-tier chipsets, giving operators the opportunity to source a range of affordable devices that are MIMO-capable.

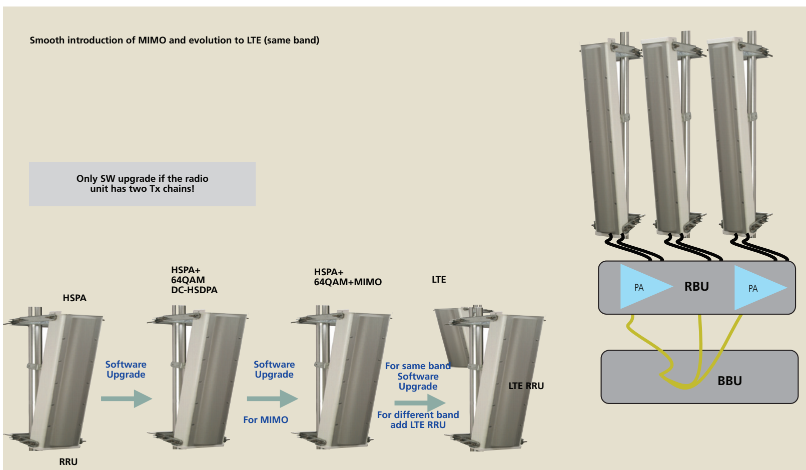


Figure 3.6: Easy Long-Term Evolution Steps of HSPA+ 6QAM+MIMO & LTE (Typical Example)

4 Experiencing MIMO: from Field Trials to Network Deployments

Since 2009, several operators have conducted laboratories and field trials of MIMO technology. Following these in-depth tests, MIMO has become a proven, mature and reliable technology and has already been commercially deployed in several networks. M1 Singapore, Vodafone Group, France Telecom, Polsat, Tim Italy, Swisscom Switzerland, Smartone Hong Kong and others have conducted MIMO trials, and some of them have already deployed or have announced clear plans to deploy MIMO on significant scale, in combination with other HSPA evolution options.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News

Vodafone Greece offers mobile broadband at 28.8 Mbps

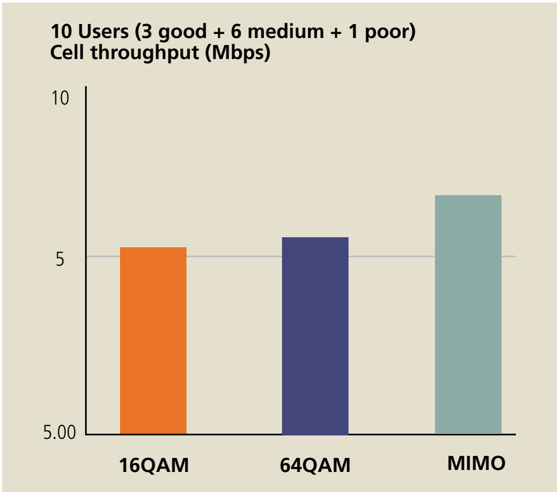
Wednesday 10 March 2010 | 08:46 CET

Vodafone Greece's new download speeds of 28.8 Mbps available via HSPA+ MIMO technology are being offered to broadband subscribers in selected areas. Internet services running at the new transfer speeds are now commercially available through the exclusive Vodafone K4505 USB Stick, which is offered at no additional cost to clients who subscribe to Vodafone Mobile Broadband tariff plans. Initially, upgraded HSPA+ MIMO Vodafone Mobile Broadband services are provided in selected areas of Athens, with plans to expand this elsewhere in the country. In addition, Vodafone continues to invest on further expanding coverage and capacity of its 3G/HSPA network across the territory.

In cases in which the operator trialed the most recent and advanced MIMO techniques, along with the co-carrier optimization features as described earlier in this paper, the results were excellent, reflecting the maturity of these features. A number of field trials, conducted in conjunction with some leading network infrastructure vendors, produced the following KPIs:

- Single user peak rate near to 28 Mbps in ideal conditions
- 25% cell throughput gain compared to 16QAM, 15% compared to 64QAM.
- 100% single user peak rate gain compared to 16QAM, 33.3% compared to 64QAM.
- Compared with 64QAM:
  - MIMO brings nearly a 30% downlink single-user throughput gain in good coverage areas and between 10% and 15% average gains respectively in medium and bad coverage (e.g. near cell edge) areas
  - Meanwhile, under a 5 MIMO users and 10 MIMO users' testing scenario, MIMO increased the cell throughput by 15%
- With the latest MIMO and HSDPA co-carrier solution, there is virtually **no perceived service impact on HSDPA legacy users**.

Figure 4.1: Field Test, Relative Average Cell Gain of MIMO Compared to 16 QAM and to 64 QAM



4.1 Case Study at 2100MHz

As with all of the world's operators, Vodafone is dealing with the ever increasing demand for packet data services. To meet this challenge, Vodafone has conducted considerable research into mobile broadband evolved techniques for HSPA, and to this end has studied "HSPA+" features – i.e. both from a network and device point of view – up to and including 3GPP Release 8 features.

Using the 2100MHz spectrum band, Vodafone has studied, and to varying degrees, deployed:

- 64QAM modulation for HSDPA (3GPP Rel'7 capability).
- "Multiple Input, Multiple Output" i.e. MIMO using 16QAM (3GPP Rel'7 capability).
- Dual Carrier i.e. the aggregation of 2 contiguous DL carriers. (3GPP Rel'8 capability).

A detailed assessment of the above three features has been completed in field in both controlled and commercial environments.
It is expected that the introduction of MIMO using 64QAM modulation will further enhance MIMO

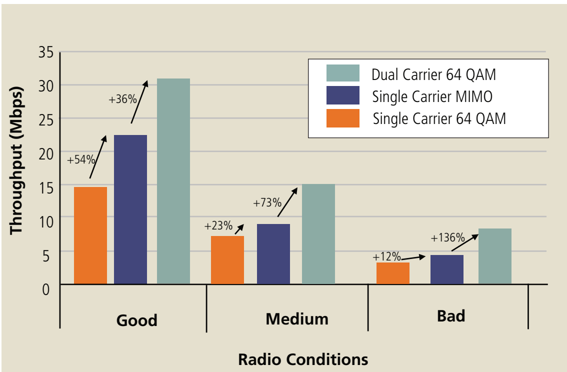
performance as will the Multicarrier feature when 3 x 5Mhz and 4 x 5Mhz carrier aggregation becomes available.

HSPA+ using 64QAM modulation alone increases the theoretical downlink peak rate from 14.4Mbps up to 21.6Mbps. Using 3GPP Rel'8 Dual Carrier permits the doubling of the theoretical peak rate achievable with a single 64QAM carrier i.e. up to 43.2 Mbps. MIMO – which was specified in the same release as 64QAM i.e. in 3GPP Rel'7 – increases further this theoretical peak rate using a 5Mhz carrier by achieving a theoretical peak throughput of 28.8 Mbps.

Figure 4.2 shows the performance (throughput) measured on a given infrastructure vendor in good, medium and bad radio conditions for a single user with maximum HSPA+ resources available (no load). The results correspond to average MAC throughput measured for each radio condition category (good/medium/bad) over at least five static points.

Figure 4.2: Field Measurement of Single User HSPA+ Performance (UDP Traffic)

When two HSPA users are simultaneously active, the difference in performance changes substantially

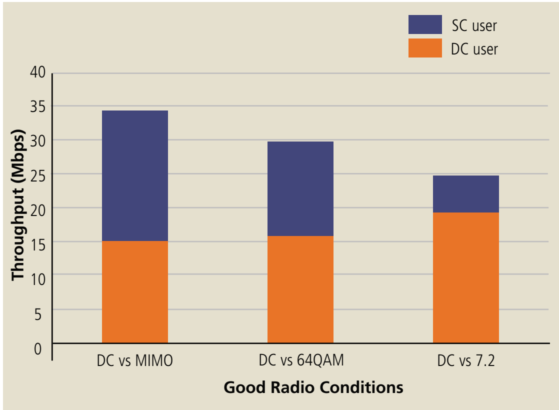


– see Figure 4.3 below which shows the throughput achieved per user for a DC user against a single carrier user (64QAM/MIMO/7.2).

This shows that MIMO provides a superior performance to DC in good radio conditions in such a multi-user scenario, but DC performs better in bad radio conditions.

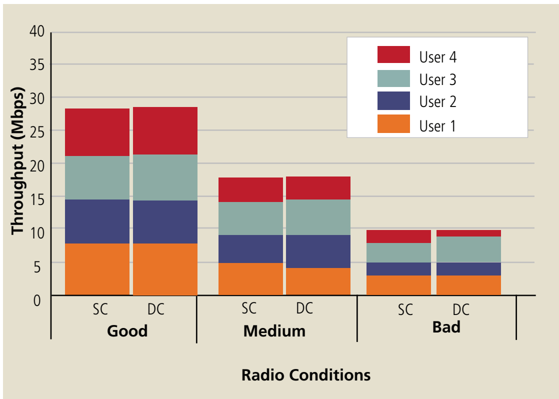
Figure 4.3: Field Measurement of Multi-User HSPA+ Performance (2 Users with UDP Traffic)

Dual Carrier provides significant improvements for a single user actively using HSPA resources in a cell



when the cell is not heavily loaded. However, the cell capacity is not increased for full buffer type traffic e.g. UDP/FTP – as can be seen in figure 4.4, which displays overall capacity provided by DC compared to capacity achieved with 2 x 64QAM carriers – i.e. the spectral efficiency of Dual Carrier using 64QAM modulation remains the same as Single Carrier using 64QAM.

Figure 4.4: Field Measurement of Dual Carrier vs Single Carrier (SIMO) HSPA+ Capacity



Vodafone lab and field assessments of the aforementioned HSPA+ features found that:

- MIMO is spectrally the most efficient of the available HSPA+ features today, and across all radio conditions, MIMO outperforms Single Carrier 64QAM (5Mhz) for static data users.
- Dual Carrier outperforms Single Carrier MIMO in medium load or unloaded conditions **(But it**

deploys double bandwidth). However, when load exceeds certain levels, MIMO will outperform DC as its higher spectral efficiency comes to the fore.

Although it has been reported that the network CAPEX required to support MIMO compared to other HSPA+ features is significant to the point of being prohibitive, Vodafone has found that this is not the case.

The vast majority – if not all – of deployed antennas in a macro-cellular network are typically cross polar already – thereby permitting the required support of Transmit Diversity for MIMO (support of minimum 2 Tx and Rx ports) – and it is not unusual that in a two carrier deployment, that there are already two radio units per sector i.e. two Power Amplifiers (PAs), which is a basic requirement for MIMO support.

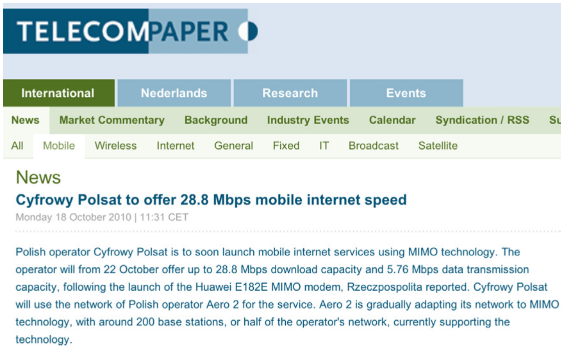
The ultimate goal is to use all of the HSPA+ approaches together, for example, combining MIMO with 64QAM with Dual Carrier offers a theoretical peak throughput of 86.4Mbps (this is defined in 3GPP Release 9). Ultimately, MIMO and Dual Carrier working together are likely to be the key enabler to extract the highest possible throughputs from the WCDMA air interface (aggregating even up to 4 MIMO carriers, as specified in 3GPP Release 10).

The main bottleneck for Vodafone and any other operator today wishing to deploy the full HSPA+ portfolio of features remains the availability of the corresponding devices. Thus far, available devices support HSPA+ features up to and including 3GPP Rel'8 features, which allows for either 64QAM, MIMO, Multicarrier, but not yet anything from 3GPP Rel'9.

Operators are today deploying a mix of these features, depending upon the environment and network demand. In the near future, the full portfolio of HSPA+ features will become available – in both the network and devices – thereby permitting operators to take advantage of the capabilities that best suits their needs.

4.2 Case Study at 900 MHz (Polsat)

During 2010, the Polish operator Cyfrowy Polsat conducted a field technology trial of MIMO, which demonstrated the effectiveness of MIMO at a lower frequency range. The Polsat network is using the 900MHz band, where the operator has launched HSPA+ 64QAM commercially, and is now evaluating the possibility to introduce MIMO as well (see TelecomPaper news story below).
The trial demonstrated the sensitivity of MIMO to the high user speed, as well as the technology's excellent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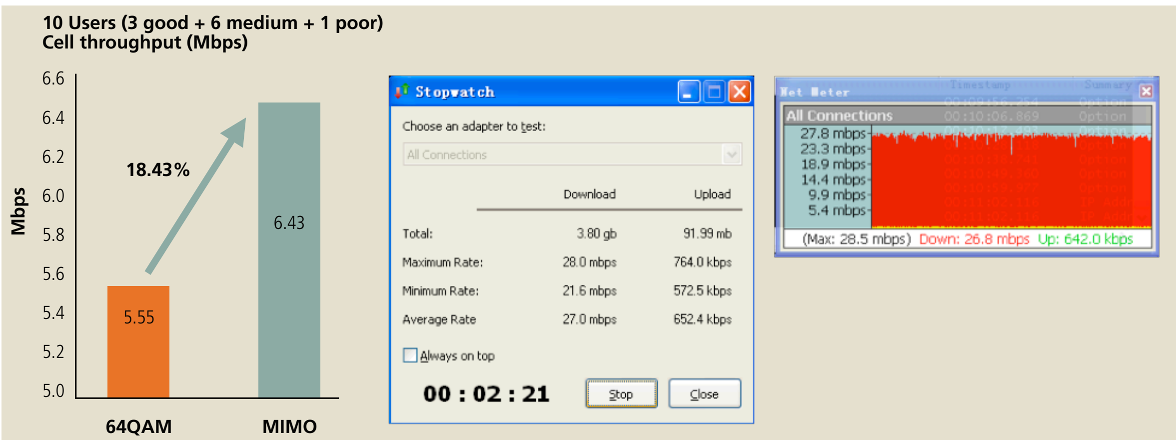
Cyfrowy Polsat to offer 28.8 Mbps mobile internet speed

Monday 18 October 2010 | 11:31 CET

Polish operator Cyfrowy Polsat is to soon launch mobile internet services using MIMO technology. The operator will from 22 October offer up to 28.8 Mbps download capacity and 5.76 Mbps data transmission capacity, following the launch of the Huawei E182E MIMO modem, Rzeczpospolita reported. Cyfrowy Polsat will use the network of Polish operator Aero 2 for the service. Aero 2 is gradually adapting its network to MIMO technology, with around 200 base stations, or half of the operator's network, currently supporting the technology.

performance in several cases within an urban environment. Polsat found MIMO delivered a peak rate near to the theoretical limit (27.16Mbps), a gain in cell average throughput and a gain in the average throughput of a single user, measured in several cell locations (see figure 4.5 below).

Figure 4.5: Average Throughput of Single User at More Than 30 Test Locations./ Peak Rate in Lab Test.

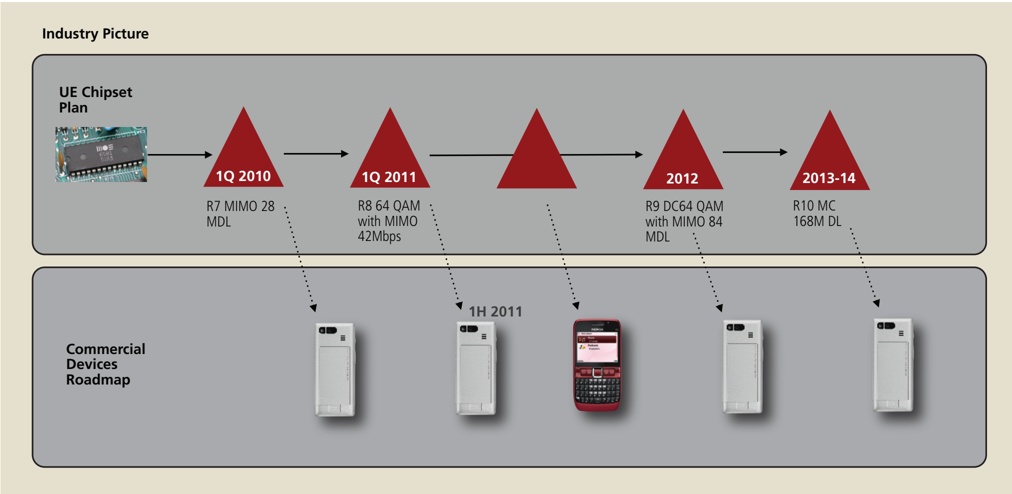


5 The MIMO Ecosystem and Outlook

Mobile operators' interest in MIMO is increasing because they are realizing that the ecosystem, including user devices and the associated chipset solutions, is now mature.

Not only have some leading infrastructure vendors been shipping MIMO-ready base stations for many years (see section 3.3.1), but the chipset-solutions for end-user devices have been available since 2009. There are now more than 10 MIMO compatible user devices (dongles, routers, etc) on the market, supporting different frequency ranges. Some HSPA dongles are hardware-prepared for MIMO support, which can be activated with a simple software upgrade by the consumer at a later stage.

Figure 5.1: Chipset and Devices Industry Roadmap, Supporting MIMO



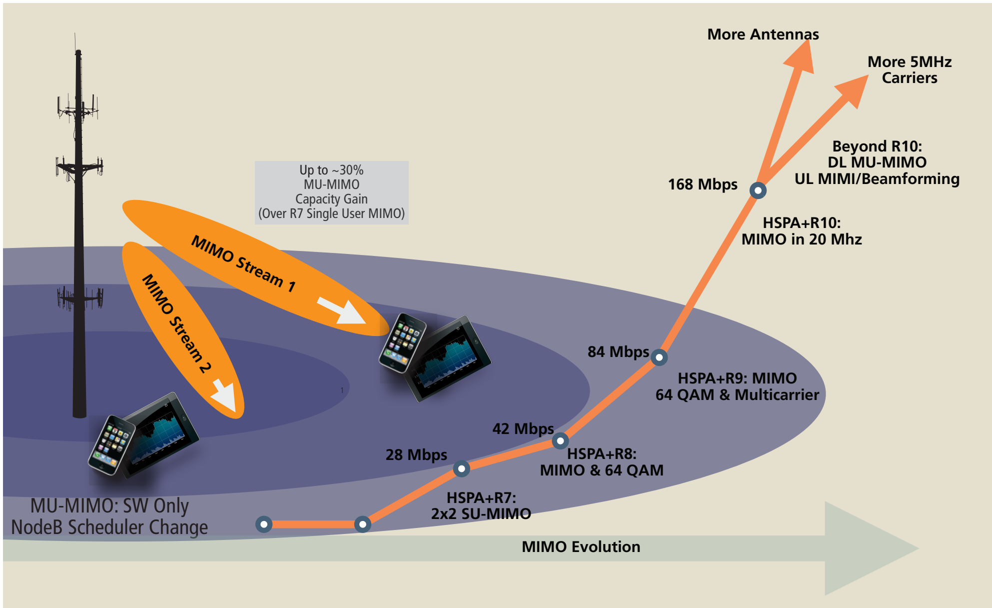
The main chipset vendors have not only announced their plans to support the next steps of HSPA evolution (R8, R9, R10, etc), including MIMO, but are also planning to deliver a MIMO solution for smartphones in 2011. It is clear that once devices have to be multimode to support LTE, MIMO will be a default feature in every multimode device, including the HSPA version.

6 MIMO Evolution in 3GPP

6.1 MIMO Continues to Evolve in 3GPP

MIMO has a prominent role in all of the HSPA releases. As shown in Figure 6.1, MIMO will continue to evolve as part of the established HSPA roadmap.

Figure 6.1: MIMO continues to Evolve in HSPA



[1]Source Qualcomm simulations. NGMN D1, ISD = 500 m, Total Overhead Power = 30% (20% for SIMO), SCM Urban: Ant Separation:4λ Correlation = 50% Full-buffer with 16 users per cell .The more users the better gain MU-MIMO gain due to more opportunities to schedule multiple users simultaneously .

HSPA Rel. 7 introduced the 2x2 MIMO on the downlink offering a peak rate of 28Mbps and the first commercial MIMO HSPA networks were launched in July 2009. In Rel.8, 2x2 MIMO is combined with 64QAM to provide 42Mbps peak speed.

The popularity of mobile broadband services delivered using HSPA and HSPA+ has increased data demand so much that many operators had to very quickly deploy multiple carriers. Rel.8 Dual-Carrier feature aggregates two HSPA carriers to offer 42Mbps peak rate, as well as increase data rates for all users in the cell. Such operators can push the performance to an even higher level by combing Dual-Carrier with 2x2 MIMO. That's precisely what Rel. 9 does, to provide 84Mbps peak rate. Rel. 10 takes it ever further, by supporting 4 carrier aggregation (in a 20MHz channel) and coupling it with MIMO to provide an impressive 168Mbps peak rate.

Rel. 9 with MIMO is expected to be commercial in 2011, followed by Rel. 10 in 2012. At the time this paper is going to print, the telecom industry was working on proposals for *HSPA+ Advanced*, which includes Rel. 11 and beyond. HSPA+ Advanced takes MIMO into many more directions – Uplink MIMO and beamforming, Multiuser MIMO in the downlink and others.

One important takeaway is that MIMO can be combined with HSPA+'s other innovative features, providing protection for the investment operators are today making in MIMO.

6.2 Leveraging Today's MIMO Investments through Multi-User MIMO

Ever since Rel. 7, the focus has always been on Single-User MIMO, which, as the name suggests, was between the base station and a specific user. Multi User-MIMO expands the same concept so that multiple users, typically in separate geographical locations, but within the coverage of the same cell, can be served using the same time and frequency resources. If there is enough separation between the users, so that the streams to them are not interfering with each other, MU-MIMO is designed to enable them to reuse resources.

This means, similar to SU-MIMO, more data is being transferred using the same resources, albeit to different users. Because of its ability to provide spatial diversity, MU-MIMO is also sometimes referred to as SDMA (Spatial Diversity Multiple Access). The advantage of MU-MIMO is that it typically only requires a software upgrade to the infrastructure supporting SU-MIMO, further leveraging operators' existing MIMO investments.

MU-MIMO provides up to a 30% increase in data capacity over that of SU-MIMO, which itself provides about a 20% improvement. So, both the MIMO schemes together offer about 50% increase compared to a non-MIMO system.

MU-MIMO will potentially be a candidate feature for Rel. 12, which is under the larger HSPA+ Advanced umbrella.

7 Conclusion and Recommendations

MIMO was standardized by the 3GPP in 2008 in release R7. During the 2nd half of 2009, MIMO network and device equipment for HSPA and LTE were delivered to the market. At that time, MIMO in HSPA networks wasn't widely-deployed for a number of reasons: the relatively scarcity of compatible devices, the perceived cost to upgrade the base station hardware, and the impact the first implementations of MIMO (based on STTD) had on legacy HSDPA users.

Since then, through the significant progress at 3GPP level and in the ecosystem, combined with smart network based optimization techniques, MIMO HSPA has become a robust and affordable technology:

Standard 2x2MIMO HSPA terminals are already in commercial use, while commercial trials and commercial applications worldwide have proven that MIMO offers significant performance and capacity gains, without compromising legacy HSDPA services.

The latest baseline performance tests conducted in several live networks run by top-tier operators found that more than 25% average cell throughput gain is achieved by an HSPA MIMO solution compared to the single transmission mode, without degrading the performance of the non-MIMO legacy HSDPA users operating in the same cell.

MIMO can fit with a wide range of network HSPA deployment strategies, independently from the number of HSPA available carriers, and is necessary for all the next 3GPP evolution paths, from HSPA (Rel 9, 10, etc) to LTE.

For operators which want to remain competitive in mobile broadband, deploying MIMO is really a necessary and cost-effective step, which improves the performance and capacity of their networks, protecting their investments. If they haven't already, mobile operators should consider investing in MIMO technology now, to fully harness the limited spectral resources and to deliver an enhanced mobile broadband experience to their subscribers.

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