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MULTI-LAYER OPTIMIZATION AND LOAD BALANCING IN HSPA NETWORKS

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Rich spectrum of alternative 3G network upgrade directions opens a debate on the applicable and convenient evolution strategy providing resources for growing data-traffic and at the same time keeping the investments under control. Efficient multi-carrier load balancing strategy is a key aspect in optimizing mobile network with guaranteeing the best possible user experience.

Keywords: *HSPA, DC-HSDPA, multilayer, load.*

Present years showed increasingly active competition on the mobile market. Considering rapid technology development (Fig.1) and its business implications, operators need to steer the market trend and take faster response than competitors in order to survive and to keep growing. Network evolution alternatives available for operators are at least impressing. For example, gradual HSPA (High Speed Packet Access) development with WLAN (Wireless LAN) or/and LTE (Long Term Evolution) offloading hotspots, convergence of all traffic classes to full IP, intersystem balancing mechanism open many possibilities for responding the demand while keeping investments balanced.

However, operators are more reluctant to big-scale investments in immature technologies expecting further reductions in capital expenditure with growing implementation confidence. Therefore, logically operators often proceed with rollout of HSPA+ enhancements at first and at the same time build internal assurance in introduction of new technologies, frequently initially introduced as offloading layers in capacity hotspots or similar small-volume deployments [1—5]. At the same time, network quality is the basis of a competition among operators as in line with the number of research reports, subscribers have started to put increasingly more attention to the quality. Assurance of subscriber experience is certainly not an easy task taking into account booming data traffic, smart phone success and constantly evolving use-models. Conventional approaches for identifying needs for upgrading of existing solutions and introduction of new technologies have to be refined to maintain CAPEX (Capital Expenditure) and OPEX (Operational Expenditure) optimally and at the same time to keep customers happy.

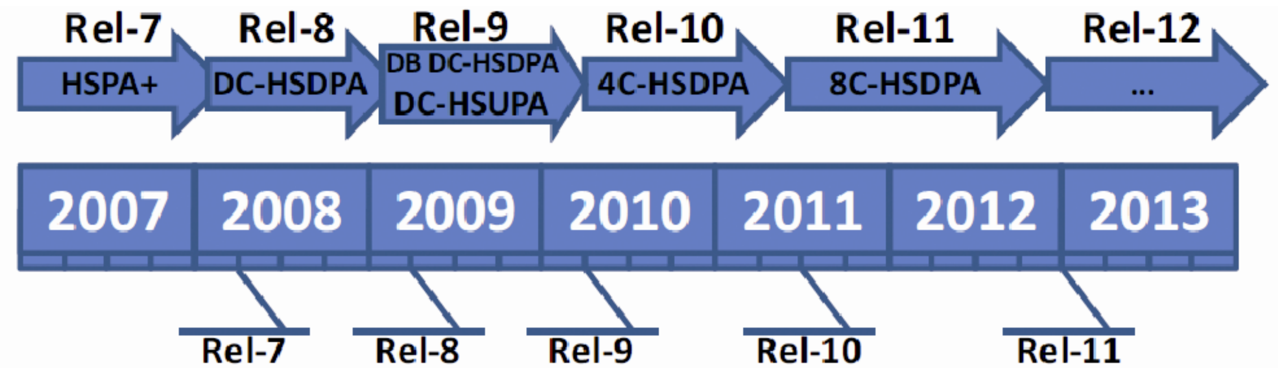

Fig. 1. HSPA multicarrier evolution in 3GPP standard releases

Traditionally in the HSPA technology evolution the possibility for aggregating two 5 MHz HSDPA cells together has been called Dual-Cell HSDPA (or DC-HSDPA), and further evolution where more than two cells can be aggregated has been dubbed N-cell or N-carrier HSDPA, where the number N refers to the number of 5 MHz HSDPA carriers aggregated together. Commonly the multiple HSDPA carrier aggregation options are often referred to as Multicarrier HSDPA. Efficient multi-carrier load balancing strategy is a key aspect in optimizing network with guaranteeing the best possible user experience. With a typical mixture of R99, HSDPA, HSPA phones and multiple "balancing-tools" offered by vendors, the task is not trivial and requires dedicated investigation and optimization. The picture becomes even more fuzzy when HSPA+ features as DC-HSDPA and/or MIMO are implemented as the multi-layer strategy needs to ensure that UEs are allocated to feature-enabled layers based on their capabilities [6, 7].

First phase of the HSPA+ upgrade involves 64QAM HSDPA (21 Mbps) and/or 16QAM HSDPA MIMO (28 Mbps) deployment. 64QAM HSDPA tends to loose its battle for first deployment with MIMO due to higher CAPEX exposure with MIMO introduction. However, different view may show that in long term MIMO can be seen as favorable for first implementation, as in fact this feature doubles the spectral efficiency, therefore preparing the network to enable 42 Mbps on a single carrier spectrum together with further available 64QAM HSDPA + MIMO feature. Moreover, the feature deployment CAPEX will not go purely to MIMO itself as with the antenna balancing feature, the extra PA (Power Amplifier) may be also used by non-MIMO users, improving the overall CQI and hence also the throughput.

Second phase of the HSPA+ upgrade involves DC-HSDPA (42 Mbps) that requires availability of 2 adjacent carriers and heavily influences the multi-carrier balancing strategy. Introduction of this feature need to carefully investigated due to site reconfiguration needs and specific scheduler activation. However, the implementation is still very straightforward and prepares the network for further introduction of DC+HSDPA+ MIMO, which enables 84 Mbps on the physical layer.

The HSPA+ roadmap for the UL includes C-plane mapping in HSPA channels allowing 5,8 Mbps in the UL, and consecutively introduction of Adaptive modulation and Coding for HSUPA enabling 11 Mbps peak rate when 16QAM is used.

Together with all the throughput-enhancing features for 2G, HSDPA, and HSUPA, an introduction of other improvements is considered with the same attention and focus. These mainly include enhanced Cell FACH operation, improved E-DPCCH performance, suitability for CS Voice over HSDPA with CPC (Continuous Packet Connectivity Feature) and HS-SCCH-less operation, DL and UL L2 Enhancements, and many other features.

Certainly, such considerations are highly dependent on the [OPERATOR's] specific configuration, network environment and local and market constrains.

The following mechanisms are available for traffic balancing across the layers:

- Idle more camping on default layer and inter-frequency cell reselections (offsets -> preferences).
- Directed RRC or/and HSDPA Layering for HSDPA/HSUPA layer directing at RRC setup (layer selected based on the defined preferences=weights, load, service type).
- Conventional IFHO (Inter-frequency Handover), which may be defined differently for HSPA, HSPA+AMR or DC-HSDPA users.
- Load- and Service-Based HO - IFHO triggered by load, or based on the service-per-layer preference.
- CAHO (Capability Based HO) – IFHO triggered by terminal capability, i. e. when terminals are not allocated to the proper layer based on their capability. CAHO may be defined differently for HSDPA, DC-HSDPA, or MIMO users.

The implementation of the multi-carrier strategy intends to maximize idle-mode and DRRC/HSDPA Layering mechanisms in order to minimize the CM (Compressed Mode) measurements that impact the resource usage and reduce the overall PS-service performance [6].

Considering allocating services across the layers and systems, generally with wide GSM coverage and TRX capacity reservation, CS voice can be logically moved to 2G layer without any customer experience compromise. In such scenario, after voice call is completed, the UE returns to 3G with idle-mode cell reselection. This approach releases more capacity for data users (R99 PS, HSDPA and DC-HSDPA) and enhances 15 HSDPA codes utilization. The resulting 3G network will in practice become data only assuming the volume of CS voice multi-RAB and video calls is small. In fact, R99 data calls could be also moved to GSM, but this would slightly affect the subscriber experience since 3G R99 data speeds are latencies are bit better then provided by EDGE.

Different layering strategies can be considered by operator for network configurations with two 3G carriers shared for R99 and HSPA traffic (and DC-HSDPA) based on the dynamic resource sharing, in particular (Fig. 2):

- If F1 shared R99/HSPA and F2 HSPA only, idle mode camping on F1 only, then HSDPA Layering (Enhanced DRRC) handles the HSDPA traffic balancing between the layers.
- Both carriers fully shared, no Idle mode default camping layers, load balancing handled by HSDPA Layering and regular IFHO.

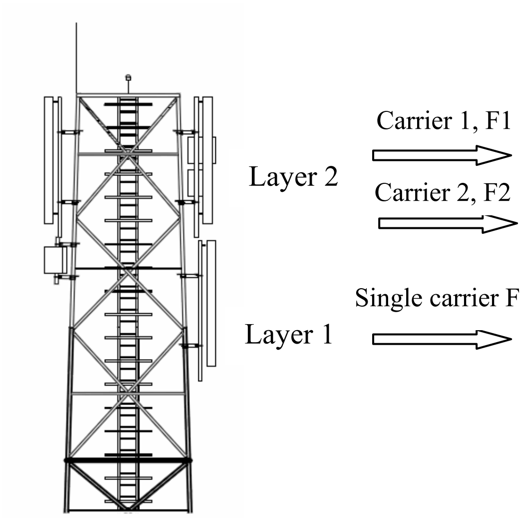

Fig. 2. RF antenna with 2 different layers and different carriers

The approach for multilayer balancing for network with three or more 3G carriers is similar, however more attention needs to be paid for accurate DRRC/HSDPA Layering configuration and for mechanisms that guarantee DC-HSDPA or MIMO feature availability. For instance, with two carriers dedicated for HSPA (and DC-HSDPA) and remaining layers dedicated for R99 or shared R99/HSPA, the following balancing strategies may be applicable:

- If all the layers belong to the same band, it is likely beneficial to define idle mode camping on layer 1 by default. Depending on the HSPA and R99 overall capacity needs, the layer 1 can be R99 dedicated on HSPA/R99 dynamically shared. The load balancing across the other layers (HSPA-dedicated) is then handled via HSDPA Layering (Enhanced DRRC). If Idle mode default camping layer (F1) is R99/HSPA shared and it is not DCHSDPA-enabled, CAHO (Capability Based Handovers) need to be implemented to handover the DCHSDPA-capable terminal to the feature supportive layer. Similarly, DCHSDPA CAHO is needed, if there are more than two HSDPA Layering candidates beyond F1.

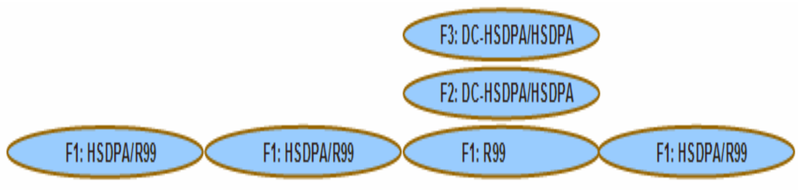

Figure 3. Hot spot DC-HSDPA deployment

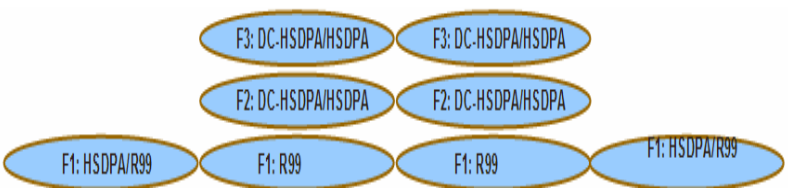

Fig. 4. High traffic area DC-HSDPA

- If the layers belong to two different bands, the configuration might closely follow the previous suggestion, however only if multi-layer load balancing mechanisms are supported by the network equipment. Otherwise, dedication of one layer from each band as a default camping layer within the band may be seen as beneficial. Then, Idle mode cell reselection offset to a higher frequency band could provide unloading mechanism for the lower band. This is often recommended as lower band layers tend to be more loaded due to wider coverage. Then, the load balancing between the layers in each band is handled by intra-band HSDPA Layering and potentially with DCHSDPA CAHO if there are more than 2 candidate layers.

Considering the DC-HSDPA deployment the following general approaches are differentiated and overviewed:

- Hot spot DC-HSDPA deployment (Fig. 3).

For example in generally single-carrier network, additional layers are deployed in line with the capacity needs. Alternatively, network is fully 2-carrier, however in data traffic hotspots additional scheduler is deployed and DCHSDPA is enabled. This solution is good for handling peak traffic in congested areas, high capacity microcells or small macro cells.

- High traffic area DC-HSDPA (Fig. 4).

Continues DCHSDPA service provided in high traffic areas such as city centers and other urban areas. Service in less busy areas is provided by a single carrier or 2-carriers non-DCHSDPA. In this scenario, additionally DCHSDPA mobility needs to be planned (definition of DCHSDPA-dedicated FMSC (Intra-Frequency Measurement Object) to guarantee that DCHSDPA-capable UEs will not be shifter to non-supportive layer.

- Full network DC-HSDPA rollout (Fig. 5).

This configuration requires significant CAPEX exposure for radio as well as transmission domain. Certainly, the DCHSDPA needs to be planned, and if more than 2 HSDPA layers are available, CAHO mechanisms should be implemented to ensure DCHSDA availability.

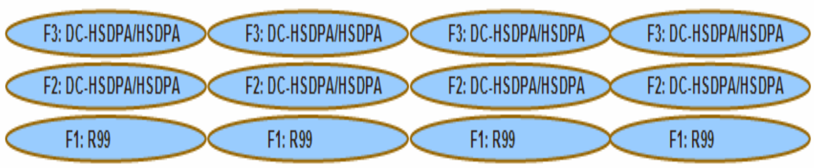

Figure 5. Full network DC-HSDPA rollout

The optimum combination of cross-layer balancing mechanism is especially challenging with layers belonging to different bands due to coverage difference, and with activated or planned HSPA+ features.

Certainly, the implementation of the multi-carrier strategy intends to maximize idle-mode and DRRC/HSDPA layering mechanisms in order to minimize the CM (Compressed Mode) measurements that impact the resource usage and reduce the overall PS-service performance. The optimum combination of cross-layer balancing mechanism is especially challenging with layers belonging to different bands due to coverage difference, and with activated or planned HSPA+ features.

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Многослойная оптимизация и балансировка нагрузки в сетях HSPA.

Богатый спектр альтернативных направлений модернизации 3G сети открывает дискуссию о выборе пригодной и удобной эволюционной стратегии, которая позволила бы обеспечить ресурсы для растущего трафика данных и одновременно сохранить инвестиции под контролем. Эффективная стратегия для балансировки многоканальной нагрузки является ключевым аспектом в оптимизации мобильных сетей, гарантирующим пользователям наиболее удобную работу.

Ключевые слова: *HSPA, DC-HSDPA, нагрузка, многослойный.*