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Functions of X2 Interface

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Abstract: ***The X2 is a new type of interface introduced by the LTE Radio Access Network. It connects neighboring eNodeBs in a peer to peer fashion to assist handover and provide a means for rapid co-ordination of radio resources. This paper considers in detail the functions that are performed over the X2 interface. X2 does not require a significant bandwidth. RAN Vendors expect that traffic levels will be only a few percent of the main S1 backhaul interface. Delay requirements are more challenging X2 delay for user traffic is additional to that on the S1, so should be as small as possible. Furthermore, interference co-ordination features proposed for future releases of LTE-Advanced are highly sensitive to small delays.***

Keywords: LTE, eNodeB, RAN, EPC, ATM, OFDMA, MIMO.

1. Introduction

The rapid adoption of data services has forced the wireless industry to rethink the way that mobile services are delivered. Compared to voice, data requires significantly more traffic and must be delivered at a much lower cost per bit in order to be profitable for operators. The industry has been working for many years on standards for the LTE RAN (Long Term Evolution Radio Access Network) and EPC (Evolved Packet Core), which address these evolving needs. Higher performance is achieved through a new OFDM Air Interface, with flexible bandwidth, native MIMO support and optimizations for delivering packet-based data service. Lower cost per bit is achieved with the widely used IP protocols. The use of IP allows operators to use Ethernet packet-based transport networks which, thanks to the success of the Internet, are now lower cost than legacy ATM-based backhaul networks. While Ethernet may be lower cost, it is packet rather than circuit switched which provides best-effort rather than guaranteed delivery of data. LTE/EPC standards therefore include end-to-end Quality of Service features to ensure essential traffic is prioritized during times of congestion. In particular, the RNC (Radio Network Controller) which was used to co-ordinate NodeBs in the UMTS RAN (Universal Mobile Telecommunications System Radio Access Network) has been removed. In LTE, most of the RNC functionality has been moved to the eNodeBs (LTE Base Stations), which now co-ordinate in a peer-to-peer fashion over a new interface called the X2. Many operators were initially concerned that X2 would require physical connections between all eNodeBs. However, X2 is a logical interface between only neighboring eNodeBs and can be switched over the existing transport network.

The paper has been organized according to the following sections: Section-1 is the introduction to the research. Section-2 consists of X2 functions. Section-3 X2 handover and followed by X2 related functions. Section-4 contains requirements for X2 handover. Section-5 contains latency. Section-6 contains X2 connectivity. Section-7 contains X2 co-ordination. Section-8 contains X2 Handover vs. S1 Handover. Section-9 contains impact of X2 delay on user throughput. Section-10 conclusion followed by references.

2. X2 Functions

The X2 interface supports exchange of information between eNodeBs to perform the following functions:

- Handover: mobility of UEs between eNodeBs
- Load Management: sharing of information to help spread loads more evenly.
- CoMP (Co-ordinated Multi-Point transmission or reception): Neighboring eNodeBs co-ordinate over X2 to reduce interference levels.
- Network Optimizations.
- eNodeB configuration update, cell activation, including neighbor list updates.
- Mobility optimization: co-ordination of handover.
- General Management: initializing and resetting the X2.Many of the key functions are described by the X2 Application Protocol, specified in [2]. These control plane signaling procedures have been standardized in order to ensure eNodeBs from different vendors are interoperable.

3. X2 Handover

Handover is required when a UE moves between coverage areas of different eNodeBs. 3G systems used a make-before-break „soft handover‟ to ensure connectivity was maintained as users moved between cells. LTE however uses a fast break-before-make „hard handover‟ which makes more efficient use of both spectral and backhaul resources. It does however create a short interruption in the connection. Packet-based services are by nature short parcels of information with gaps in between, so providing the handover interruption time is short, it will not impact the quality of the service.3G handover is co-ordinated by the RNC this is not present in LTE, and so eNodeBs themselves co-ordinate the handover. The X2 interface is not mandatory, and in its absence eNodeBs arrange the handover over the S1 interface via the core network. However, X2 handovers have the benefit of reduced preparation times and lower core processing load.

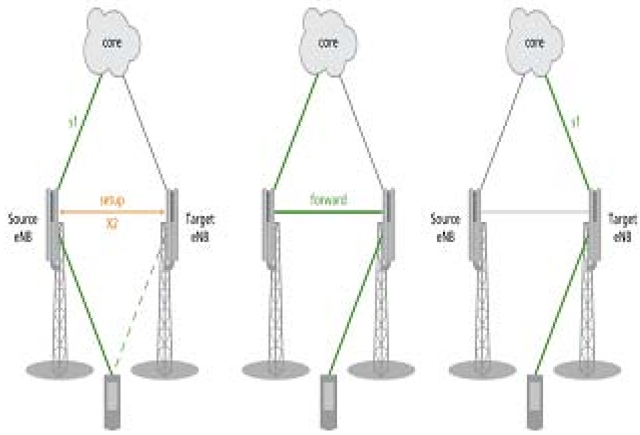

Figure 1: X2 Handover. [4]

1) Preparation

a) A UE approaching the edge of its cell will start detecting signals from neighboring cells.

b) Measurements of signal strength and quality will be reported back to the serving or source eNodeB.

c) At some point the source eNodeB may decide that the UE would be better served by one of its neighbors, and so it sends a handover request to the Target, over the X2.

d) The target will perform admission control and if it has sufficient resources, it will confirm the handover, and provide various IDs and security information back to the source.

2) Execution

a) The source eNodeB sends a handover command to the UE which includes the information needed to connect to the target.

b) The UE then retunes and connects to the target.

c) At this point the core network is still sending the users‟ data to the source eNodeB, which is forwarded over the X2 to the target and then to the UE. This data forwarding is the most significant component of X2 traffic.

3) Completion

a) Once the UE is connected, the target eNodeB sends a „path switch‟ command to the core.

b) The core updates the S1 connectivity for the UE to route directly to the target eNodeB.

The X2 handover reduces the handover setup time and hence reduces the chances of handover failure when the network cannot keep up with the rapidly changing radio conditions of fast moving UEs. X2 forwarding also helps minimize packet delay variation, as forwarded packets arrive at the target eNodeB sooner. X2 handover reduces core processing and backhaul requirements, as the signaling can be kept local to the source and target eNodeBs.

3.1 Handover related functions

The X2 Application protocol also includes procedures to optimize handover performance:

Mobility parameter management Neighboring eNodeBs can recommend updates of handover thresholds.

Handover history reports: Records of historical handovers can help in optimization, e.g. to reduce ping-ponging.

Radio link failure: The target eNodeB can quickly inform the source, if the UE loses contact during a handover. The source may then re-establish the link for another attempt.

4. Requirements for X2 handover

The forwarding of the user plane data dominates bandwidth requirements for the X2 interface, and it may be in the order of Mbps. Control plane signaling is likely to be of the order of kbps, and can therefore be considered negligible.

Although LTE might be capable of delivering data rates of the order of hundreds of Mbps, these only occur when the user has an excellent radio link with an eNodeB and no interference from others. This is not the case for a UE at the cell edge in handover. By definition, a UE in handover receives similar signal levels from the source and target eNodeBs. This results in low signal quality and lower data rates.

5. Latency

X2 handover is no more sensitive to latency than S1 signaling or user traffic, so the same requirements apply. NGMN requirements are 10ms end-to-end round trip delay, and 5ms is recommended [5]. When used for data forwarding, the X2 delay must be added onto the S1 delay, and so should be as small as possible. Sub 1ms delays are therefore desirable.

eNodeB vendors have the following estimates of X2 bandwidth:

- "...the X2 interface needs little bandwidth–a maximum of 3% of the amount required by the S1 interface", Huawei [4]
- "X2 is < 2% of S1 traffic, more likely 1.6%", Huawei [4]
- "typically see an average of 5% and that's consistent with customers‟ views" Alcatel-Lucent [2]
- "3 to 5% of S1 is a generous allowance for X2", FT/Orange, Transport Networks for Mobile Operators Conference, 2010

All vendors express X2 throughput as a percentage of that over S1, which in turn depends on the configuration of the eNodeB supported. Wider channel bandwidths (up to 20MHz) and higher order MIMO (up to 4x4 for early LTE releases) result in more traffic over S1 and therefore X2. X2 traffic is not constant, and depends on the degree of mobility between cells. For example, an X2 link between eNodeBs covering a train line may generate more traffic than an X2 between eNodeBs covering nomadic users in an office.

6. X2 connectivity

- X2 does not require a dedicated physical connection between eNodeBs.

- It is a logical interface that can pass over the existing IP transport network.
- X2 does not require L3 Routing.
- Where possible, switching can be used and is preferable for the higher performance achieved.
- X2 interfaces are not needed between ALL eNodeBs in a network.
- X2 interfaces are only needed between neighboring eNodeBs (i.e. those that control cells with overlapping coverage areas). It is only between neighbors that handovers will occur or interference co-ordination will be needed.

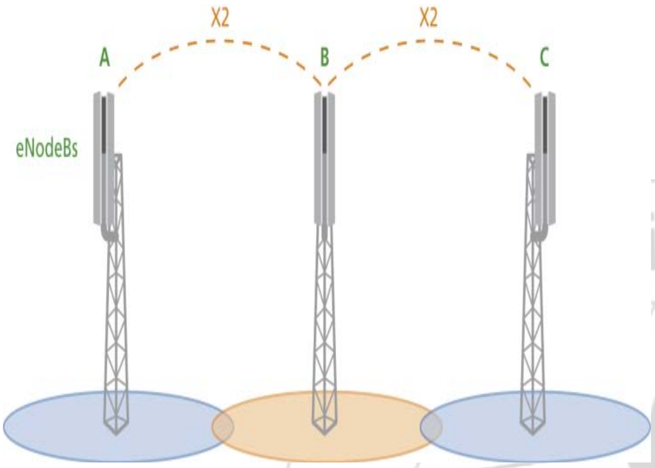

Figure 2: X2 interfaces are only needed between neighboring eNodeBs

Figure 2 provides a simplified illustration, where A&B are neighbors as well as B&C. However, A&C would not be neighbors as their coverage does not overlap. Real world propagation is not as clear cut, and there are many cases where coverage overlap occurs between non-adjacent cells, especially in dense networks covering city centers, for example. The following vendor comment and NGMN requirement suggest that anything up to 32 X2 interfaces will be needed per eNodeB.

- "With mixture of macro/micro eNBs, one eNB may need connectivity up to ~20..30 neighboring cells", Huawei [4]
- "Typically up to 6 operators and 32 X2 interfaces MAY be envisioned per e-NB". NGMN Requirements [5]

7. X2 Co-ordination

In a cellular network, some UEs will be able to hear (or be heard by) more than one eNodeB. In the first release of LTE, the serving cell is the one with the strongest signal, and the other signal is considered an interferer. If these two signals are at similar levels, they will interfere with each other and result in poor performance for the user. It can be shown that capacity can be improved if the two cells co-ordinate to use different frequency or time slots [6]. In LTE-Advanced, rather than just avoiding interference, cells can instead harness the energy from the multiple signal paths in order to achieve further capacity gains.

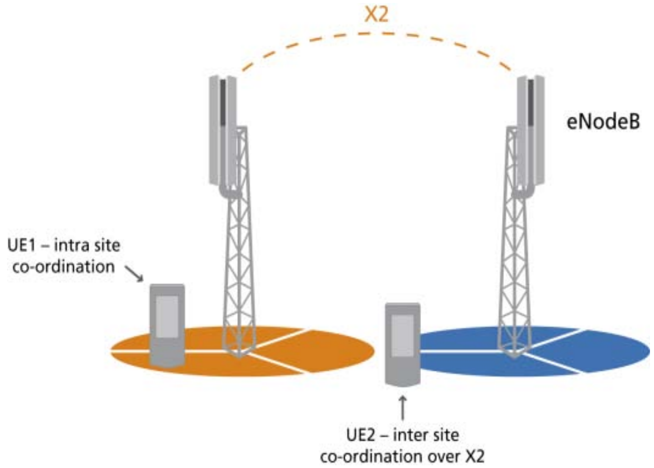

Figure 3: UEs requiring intra- and inter-site co-ordination

Most cellular networks today use tri-cellular Base Stations shown in Figure 3. This diagram illustrates two different scenarios for co-ordination:

- UE1 sits on the boundary of two cells which are controlled by the same eNodeB. In this scenario, any co-ordination is internal to the eNodeB and so can benefit from almost zero latency and wide bandwidth signaling.
- UE2 sits on the cell boundary between two different eNodeBs. Any co-ordination information must therefore pass over the X2 interface, and may be limited by its bandwidth and latency capabilities.

LTE and LTE-Advanced include several schemes for "Co-ordinated Multi Point transmission and reception" [5], each with varying degrees of information sharing as follows:

Inter-Cell Interference Co-ordination (ICIC, Rel-8 LTE):
- For the downlink eNodeBs share information with their neighbors about frequency and time resources. The neighbors can avoid using these same resources for their cell edge users.
- For the Uplink, eNodeBs share information on the interference they are receiving from their neighbors. The serving cell then learns which UEs are causing the interference, and can co-ordinate their transmissions.
- LTE-rel8 provides semi-static co-ordination of resources of the order of a few seconds.

Co-ordinated Scheduling/Beam forming (CS/CB) (LTE-Advanced):
- LTE Advanced enhances the rel-8 ICIC scheme to dynamic co-ordination where resources can be co-ordinated as rapidly as on a per 1ms sub-frame basis.
- Frequency, time and beam forming information can be co-ordinated.
- This requires lower latency and higher bandwidth signaling over X2.

Joint Processing (LTE-Advanced):
- Joint Processing (JP) differs in that the user data is present at multiple eNodeBs.
- Transmission or reception can be co-ordinated to rapidly select the best cell, or even combine signals from multiple cells coherently.

- JP requires significantly more backhaul bandwidth than the other schemes.

8. X2 Handover vs. S1 Handover

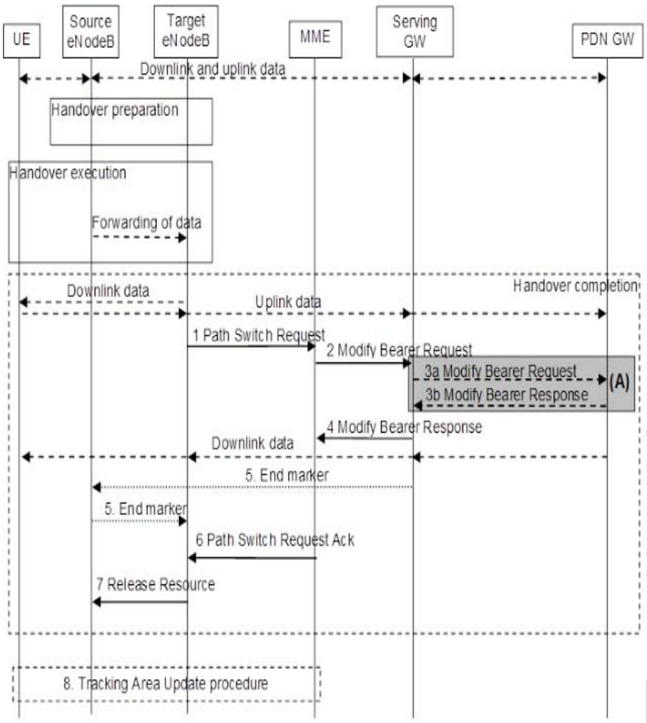

Figure 4: Procedure of X2 handover

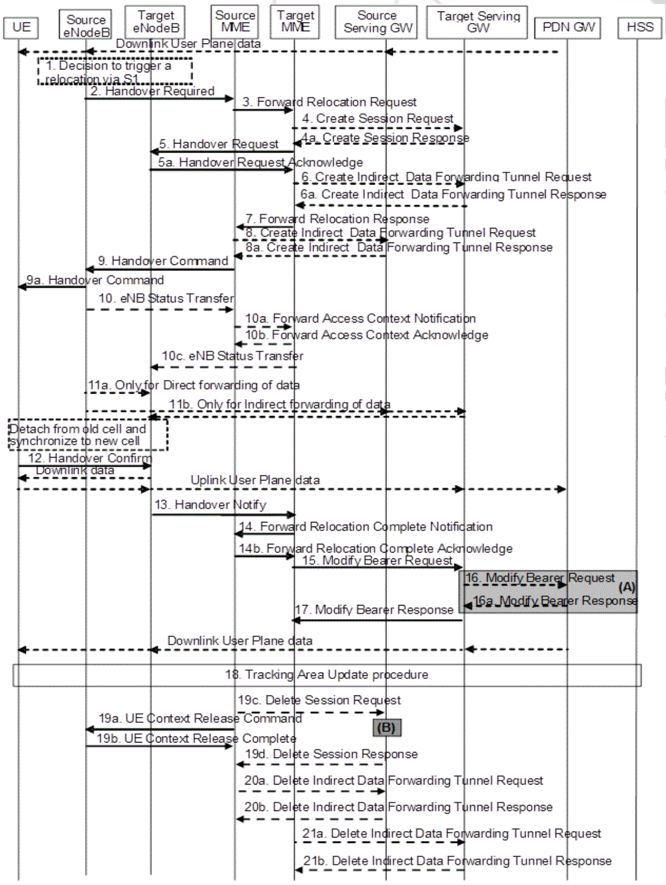

Figure 5: Procedure of S1 handover

9. Impact of X2 Delay on User Throughput

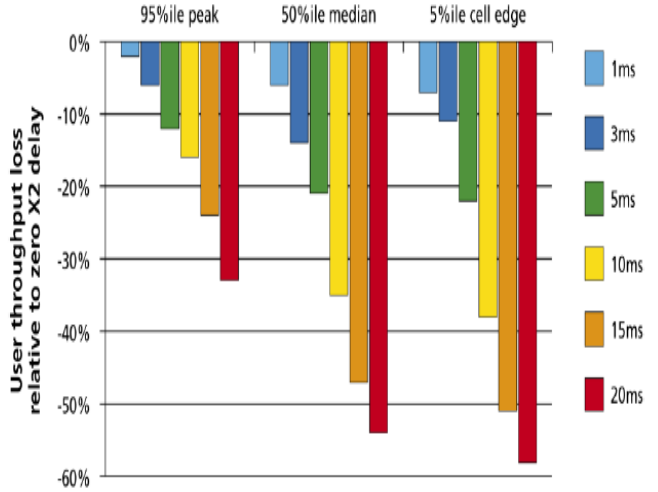

Figure 6: Impact of X2 Delay on user throughput with CoMP Scheme.3Km/h users assumed

10. Conclusion

In this paper the authors present how X2 interface provides a means for sharing information between neighboring eNodeBs to improve handover and to reduce mutual interference. The X2 carries both control plane signaling and forwarded user plane data also X2 handover is no more sensitive to latency than S1 signaling or user traffic, so the same requirements apply.

References

[1] Backhauling X2, Cambridge Broadband Networks limited, http//:www.cbnl.com/sites/all/files/userfiles/files/Backhauling-X2.pdf
[2] "X2 application protocol (X2AP)", 3GPP TS 36.423 V9.4.0 (2010-09).
[3] "X2 data transport", 3GPP TS 36.424, v8.5.0
[4] "LTE requirements for bearer networks", Huawei Publications, June 2009, http://www.huawei.com/publications/view.do?id=5904&cid=10864&pid=61
[5] "NGMN Optimized Backhaul Requirements", Next Generation Mobile Networks Alliance, August 2008, http://www.ngmn.org/uploads/media/NGMN_Optimised_Backhaul_Requirements.pdf
[6] "LTE Traffic Webinar", European Comms, 6 October 2010, http://www.cbnl.com/news/articles/European_comms_LTE_Webinar_v2.pdf