Evolution of the Evolved Packet System (EPS)

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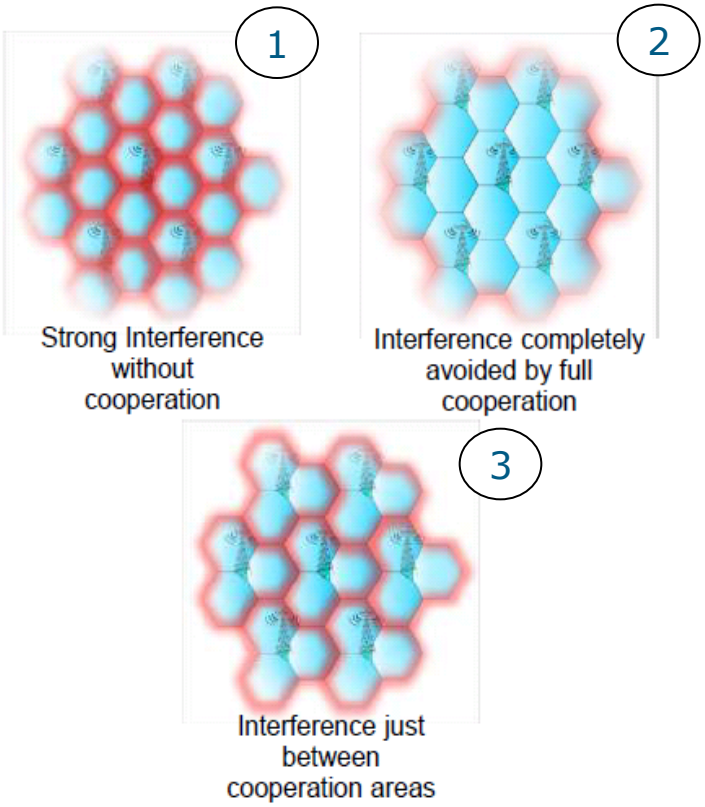
Scene Setting

The Road Ahead For Mobile.

- LTE Release 8 networks are widely deployed and operationally stable.
- Most operators seem to be adopting 2 band CA in targeted areas as the next evolutionary step.
- We all acknowledge that it will be a challenge to continue adding capacity to meet the projected exponential growth of traffic.

- Some operators are actively deploying the "small cell" layer – entering the era of HetNets.
- ***But what effective and field proven tools do we have to combat intercell interference?***
- ***If we deploy small cells in volume can we retrospectively add cooperative techniques?***
- ***If we add small cells how can we offload the macro in controlled and deterministic manner?***
- At present pace, if we keep building out LTE capacity with no cooperative techniques we will be left with the situation depicted in figure 1.
- The consequences of figure 1 mean that we are not maximising our bang for buck in terms of potential capacity.
- Which will lead to more (non-optimal) investment – but figures 2 and 3 highlight a smarter way through cooperative techniques…



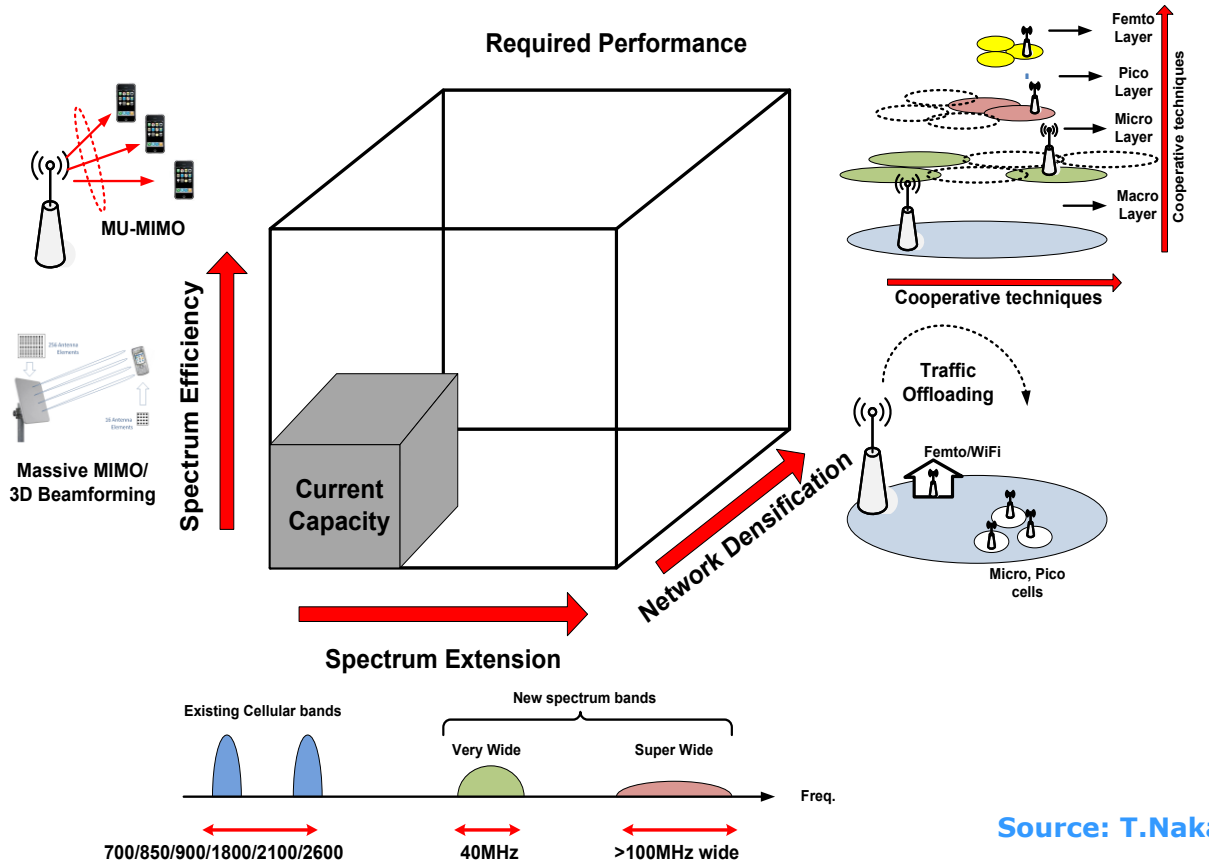
[Ref: Svensson, 2013]

A 3-Prong Approach to Address MBB Growth

- The long range view for meeting future demand necessitates further innovation in a 3-pronged approach.

- Capacity growth must be addressed across 3 dimensions:

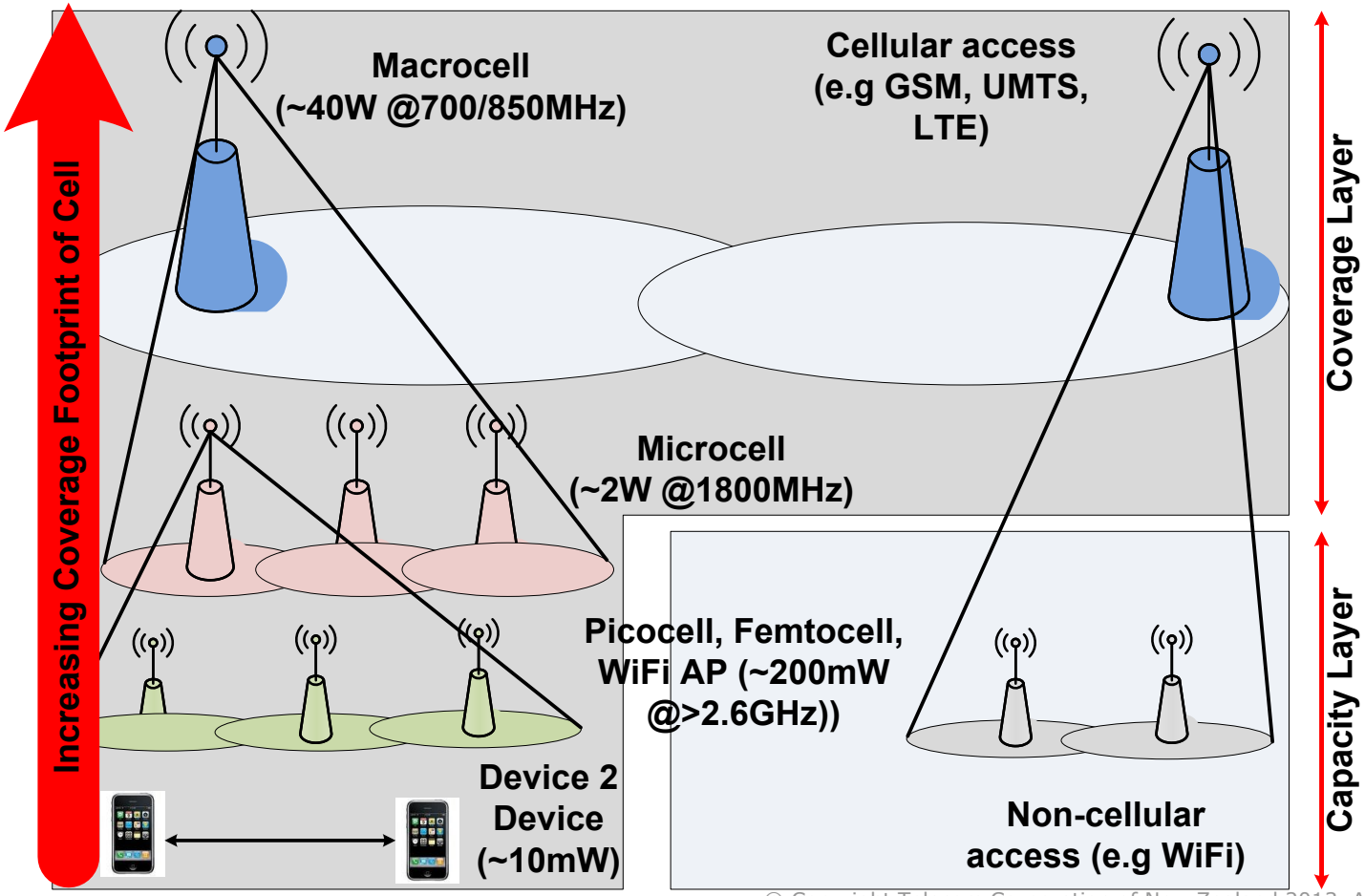
1. Technology improvements (LTE-A,B, -> 5G)
2. Network densification (small cells, cooperative techniques, offloading, WiFi etc)
3. New bands (with larger carrier bandwidths ->WRC15)



Source: T.Nakamura, NTT DoCoMo

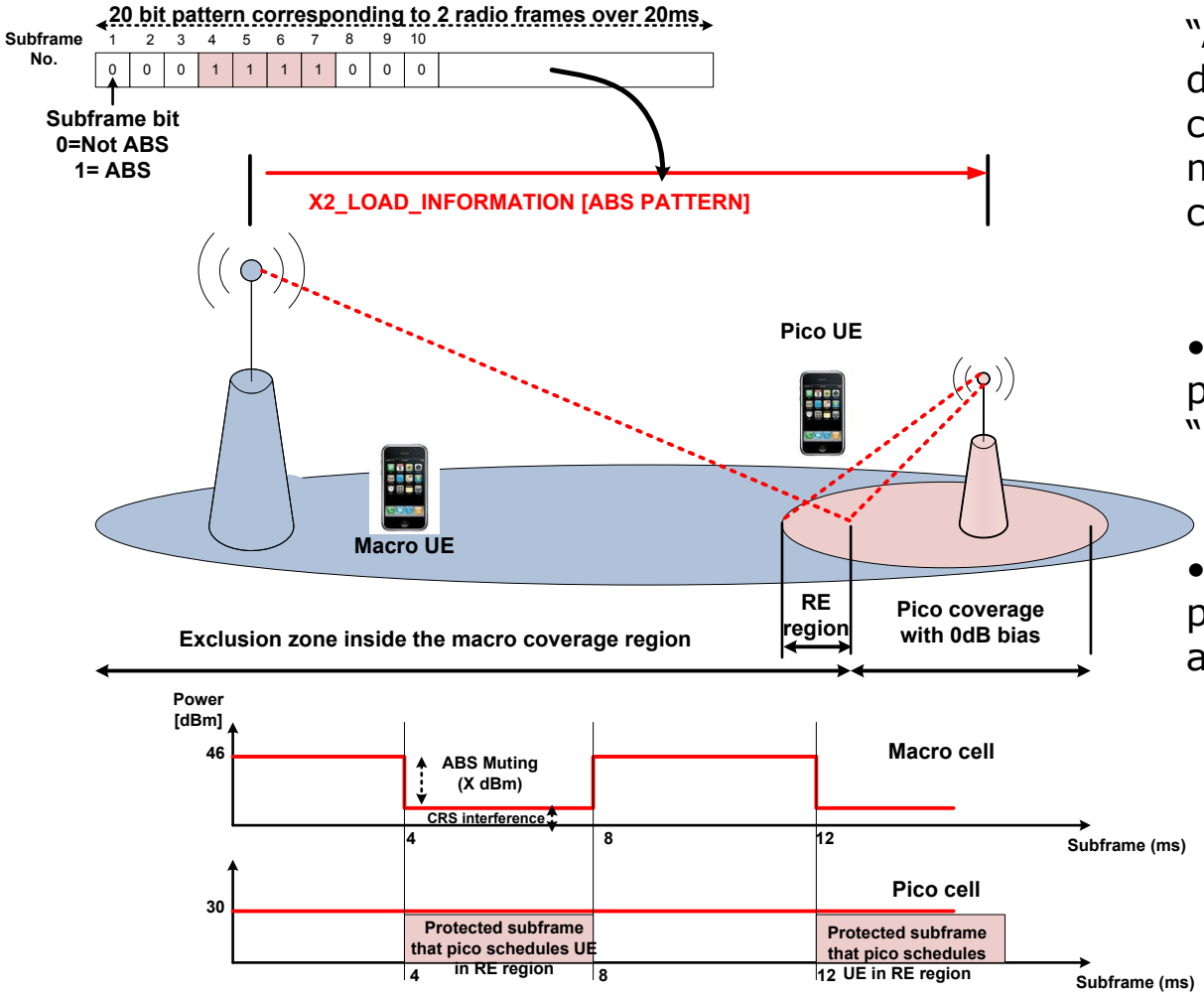
Layers within the Hierarchy

- The future mobile landscape will be ***Multi-Tiered*** in the RAN, commonly referred to as Heterogeneous Network (or HetNet)
- The HetNet paradigm will extend beyond a macro and a ***single*** small cell layer, encompassing both licensed, and unlicensed band technologies as shown below.
- Behind the scene of this landscape will be ***effective cooperative and mobility robustness mechanisms*** to enhance system capacity and offloading capability.



Radio Access Network Topics

HetNet Enabler: eICIC and CRE



- eICIC uses a concept called "Almost Blank Subframe" - a time domain technique that reduces cell edge interference between a macro and pico node in co-channel deployments.

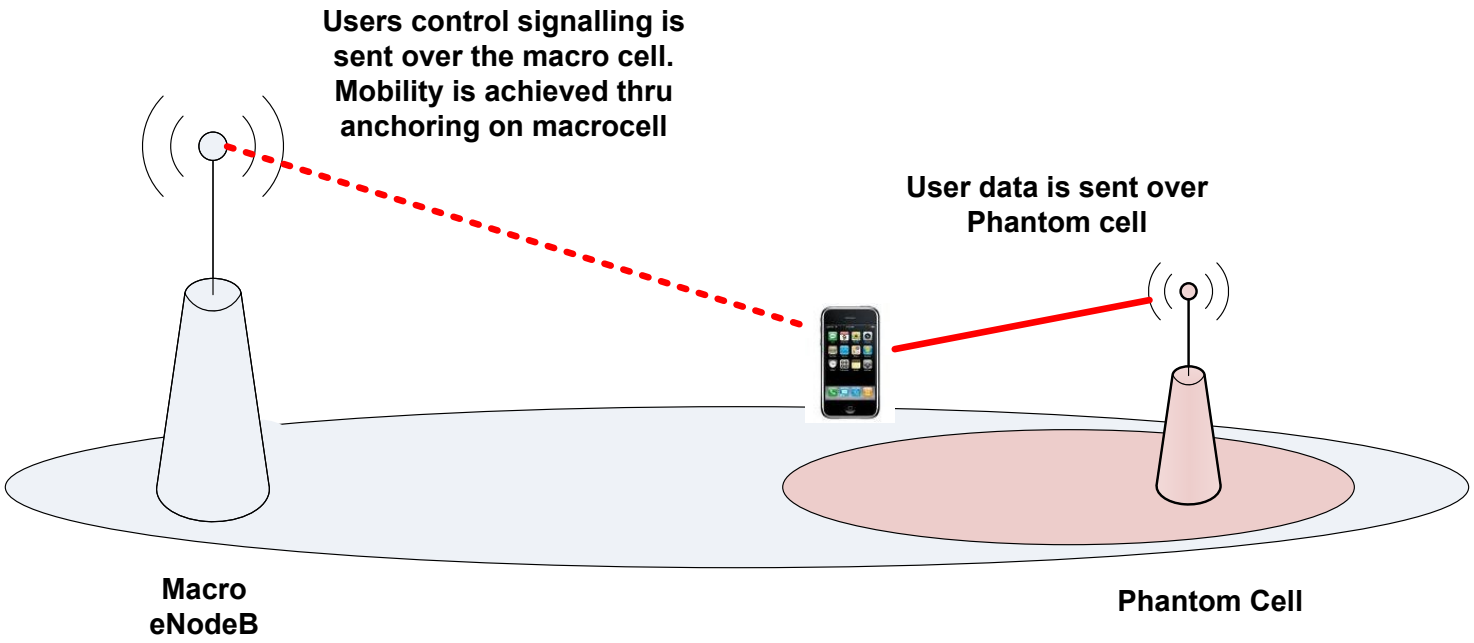
- Cell Range Extension allows the pcio to reach into the macro cell's "exclusion zone".

- Research suggests best offload performance occurs when ABS and CRE are used together.

Ref: IEEE Wireless Comms, Feb 2013, "Multicell Cooperation for LTE-A HetNet Network Scenario's", B.Soret et al

HetNet Enabler: New Carrier Type (NCT)

- NCT for the Downlink is a new concept being discussed in 3GPP Rel12.
- NCT is a stripped down (or lean) version of current cells with minimum common control channel overhead.
- Therefore it is not detectable to a device – i.e. UE must be directed by the macro cell.
- The key advantage in this scheme is related to the reduction in interference that would otherwise be generated through Reference Signal and other common channel transmissions (co-channel deployments)
- The macro layer is used as an anchor for vital control and mobility procedures and hence the UE is ***dual connected***.
- Results show that use of NCT can boost 5th-percentile rates upto 70% over Rel8 Legacy Carrier Type operation under low loads and 20% under high loads*



* IEEE Comms Magazine, Feb 2013, "A Lean carrier for LTE", Hoymann et al

HetNet Enabler: Cooperative Communications

- As we saw in the introduction, simply building out LTE capacity with conventional interference mitigation approaches (eg. Down tilting, power control etc) will lead to sub-optimal system capacity and over investment in CAPEX.

- Cell edge, where the bulk of users lie, needs to be the focus of cooperative techniques to lift SINR and hence capacity.

- Many cooperative schemes have been developed. These schemes allow multiple base stations to formulate a cooperative cluster, and either coordinate to ***avoid interference*** or coordinate to ***constructively exploit*** interference.

- In 3GPP Release 10 and 11 these have been referred to as CoMP, categorised into three types:

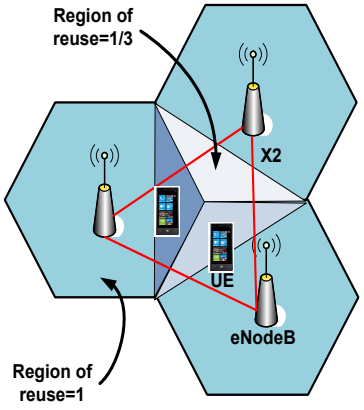
    1. **Coordinated Scheduling** (e.g. (e)ICIC) – a cooperating cluster agree which resources experience the most interference and hence derive partial reuse on such resources. This can be achieved with preconfigured fractional (or soft) reuse schemes or determined on a dynamic basis through exchanging interference reports over the X2 link.

    2. **Coordinated Beamforming** – the cooperating cluster shares CSI info for cell edge users such that each eNodeB can determine precoding matrices that will ensure beams concentrate energy only to the desired UE. The CSI exchange is done via the X2 link.

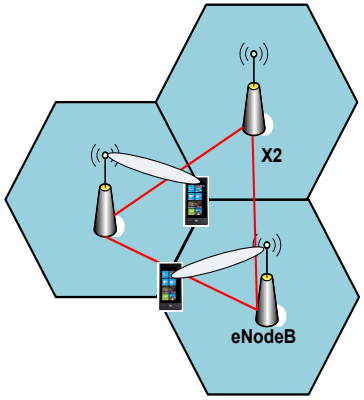
    3. **Joint Processing** – the cooperating cluster acts as a virtual antenna array, whereby multiple sites transmit to the UE simultaneously. Constructively using transmissions which would otherwise be considered as interference. This scheme requires CSI and user data to be present at every member of the cluster. X2 is used to facilitate this info exchange.

HetNet Enabler: Cooperative Communications

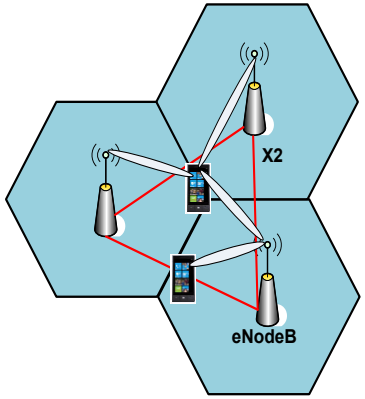
- The largest gains come from the JP category of CoMP schemes. In Foschini's paper, gains of upto 300% (using ER-ZF-CCT for 4x4MIMO) where shown for the MU-MIMO based JP scheme.
- However in practice, 3GPP simulations show only modest gains of 20~30%.
- The major sources that contribute to the loss in gains are backhaul performance (<0.5ms RTT), accurate CSI and quantization errors of CSI (4 bit encoding), and reference signal collisions.
- ***Does this mean that we can only implement CoMP types (a) and (b) in practical systems? Will that be worth the investment?***
- ***How can we future proof current deployments for such cooperative schemes?***



(a) Coordinated Scheduling



(b) Coordinated Beamforming



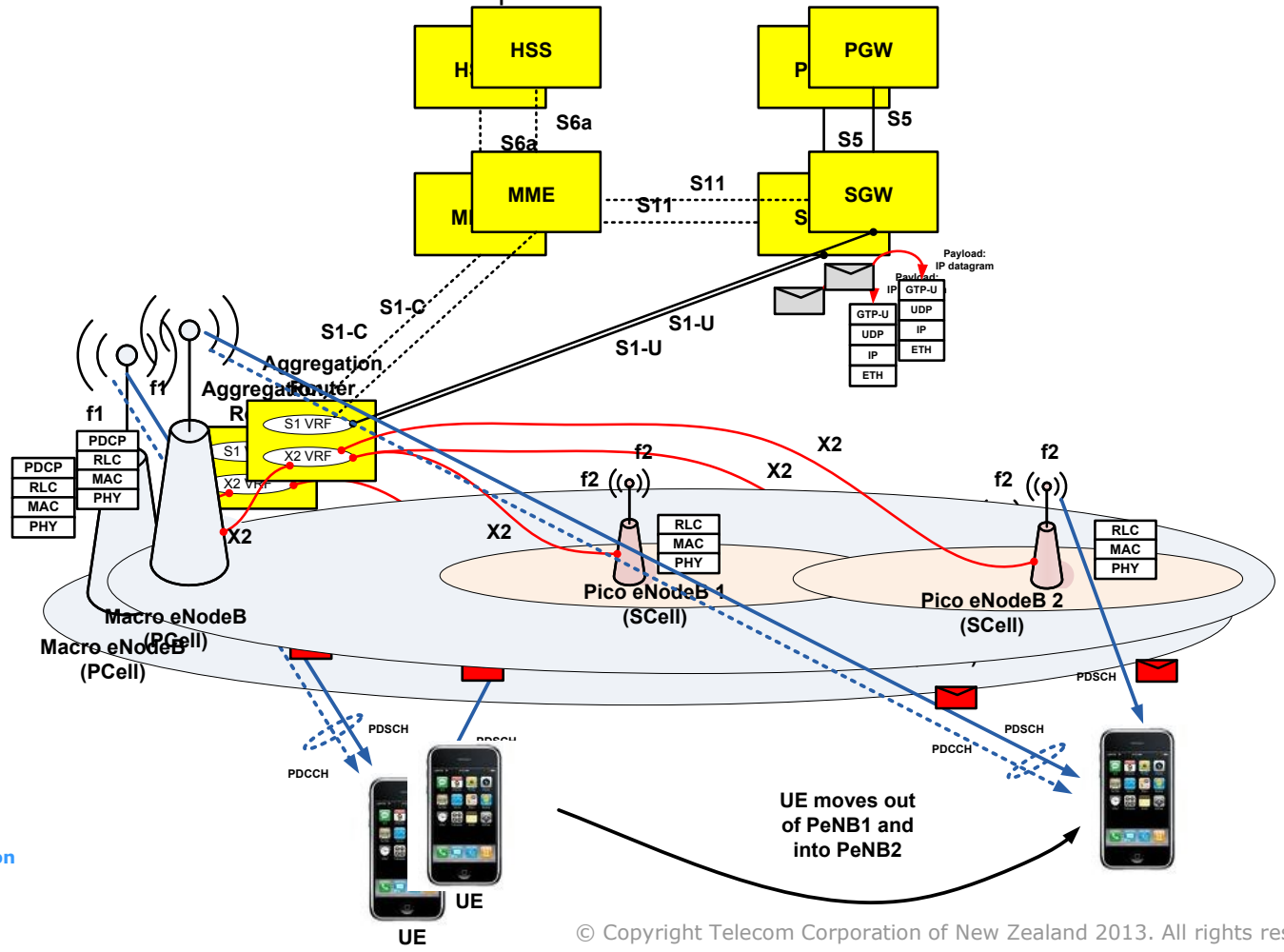
(c) Joint Processing

Ref: IEEE Comms Magazine, Aug2013, Biermann et al, and Wireless Comms, G.J Foschini, "Coordinating multiple antenna cellular networks to achieve enormous spectral efficiency"

ER-ZF-CCT: Effective Rate, Zero-Forcing, Coherently Coordinate Transmission

HetNet Enabler: Multi-Flow Aggregation

- NCT and Carrier Aggregation give rise to the concept of "***dual connectivity***" – i.e being actively attached to 2 or more cells concurrently.
- This concept is being extended above the PHY and MAC layers (where NCT and CA operate) in capability referred to as Multi-Flow, which facilitates both capacity and mobility robustness.
- This work is being discussed in 3GPP Rel12. The concept is illustrated below.

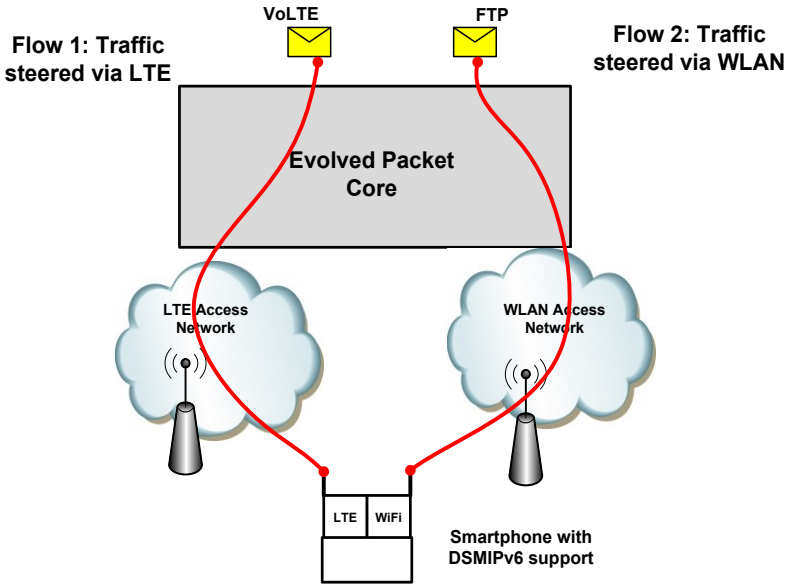


Ref: 3GPP TR36.842, "Study on Small Cell Enhancements – Higher Layer Aspects"

Core Network Topics

HetNet Enabler: IP Flow Mobility (IFOM)

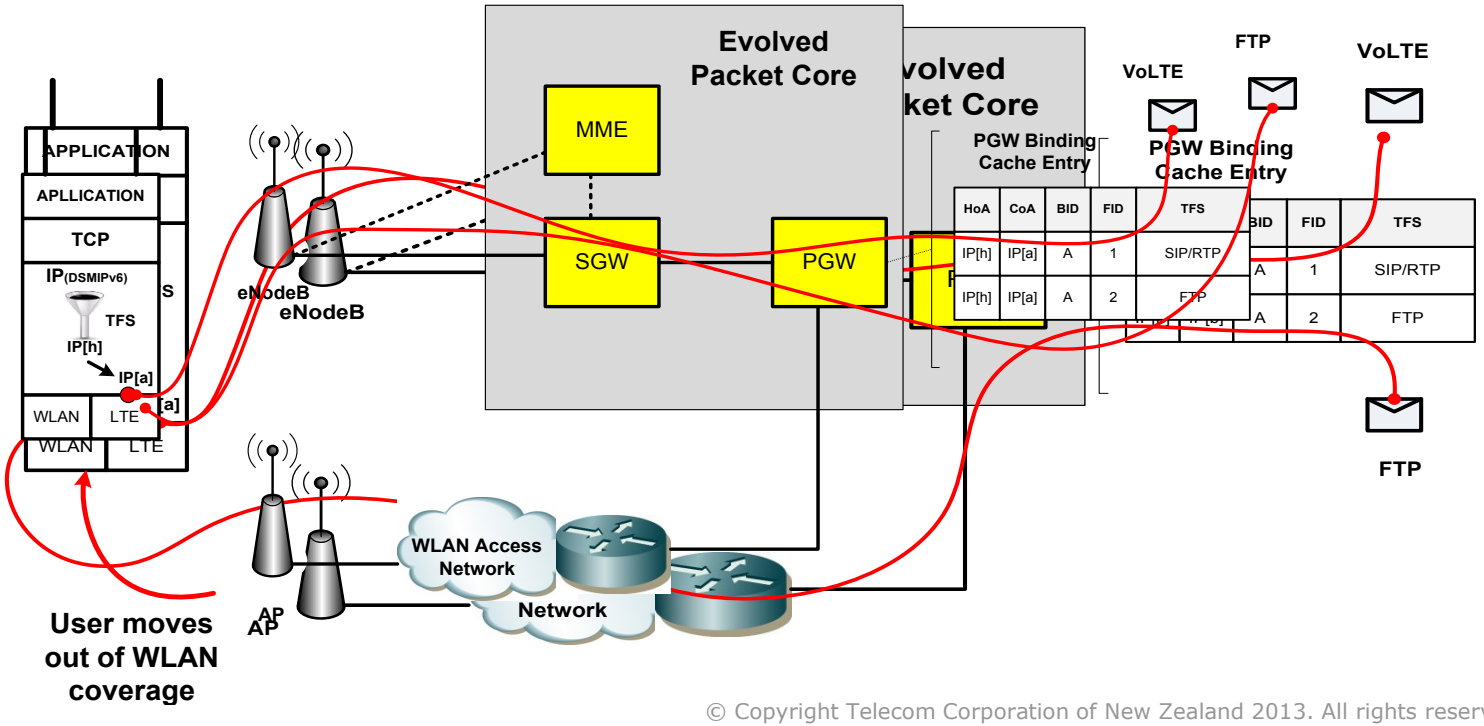
- Through the adoption of Mobile IP based protocols, 3GPP paved the way for non-cellular access networks like WiFi, WiMAX etc to be integrated to the EPC.
- The integration of WiFi to the EPC, allows the addition of WiFi Access Points as members of the small cell layer.



- IP Flow Mobility (IFOM) was standardised in 3GPP Release 10 (TS23.261) .
- IFOM allows the network to steer traffic across LTE and WiFi access based on traffic policies which can be pushed to the device.
- The device is then able to maintain concurrent flows, move flows between the access types, or combine flows into a single flow.
- The capability is based on ***Dual Stack Mobile IPv6 (or DSMIPv6).***

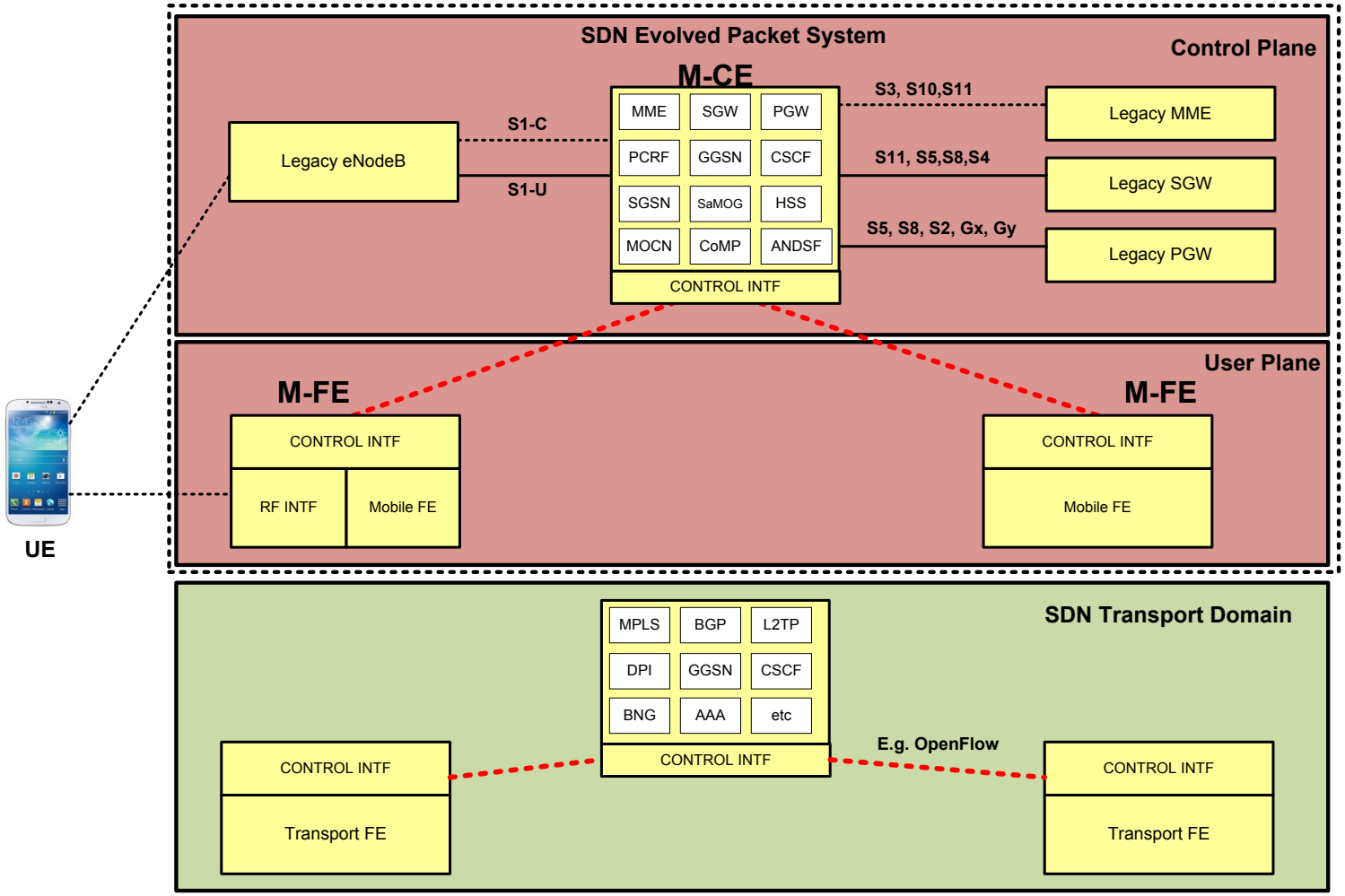
A Closer Look at Flow Mobility

- Below we see a UE with WiFi and LTE operate concurrent sessions across the WLAN and LTE networks.
- In the example, a user is enjoying the benefits of the high data rate WLAN for their FTP download while receiving a quality assured connection for their VoIP call over LTE.
- The DSMIPv6 protocol allows traffic flow selectors to be installed at UE and PGW to filter and steer the relevant applications over the respective access network connections.
- Using Flow Mobility, when the user moves out of WiFi coverage, it is possible to move the FTP session to the LTE access network connection through a DSMIPv6 signaling message from UE to PGW (i.e. via a Binding Update).



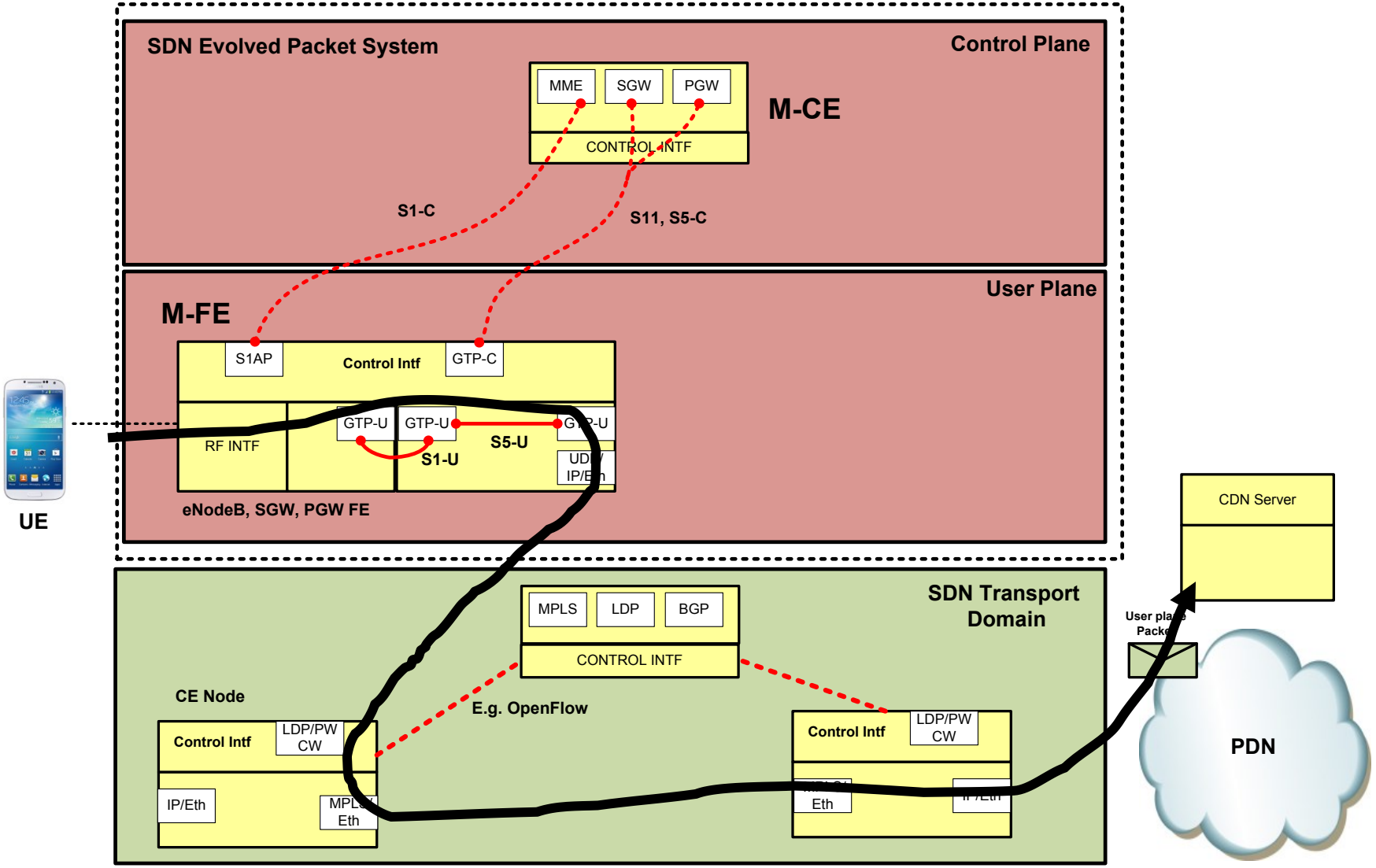
SDN in Mobile Networks – a New Functional Architecture

- When we apply SDN concepts to the mobile and transport domains we arrive at the functional architecture depicted below. Two new entities are shown, namely the Mobile Forwarding Entity (M-FE) and Mobile Controller (M-CE) Entity.



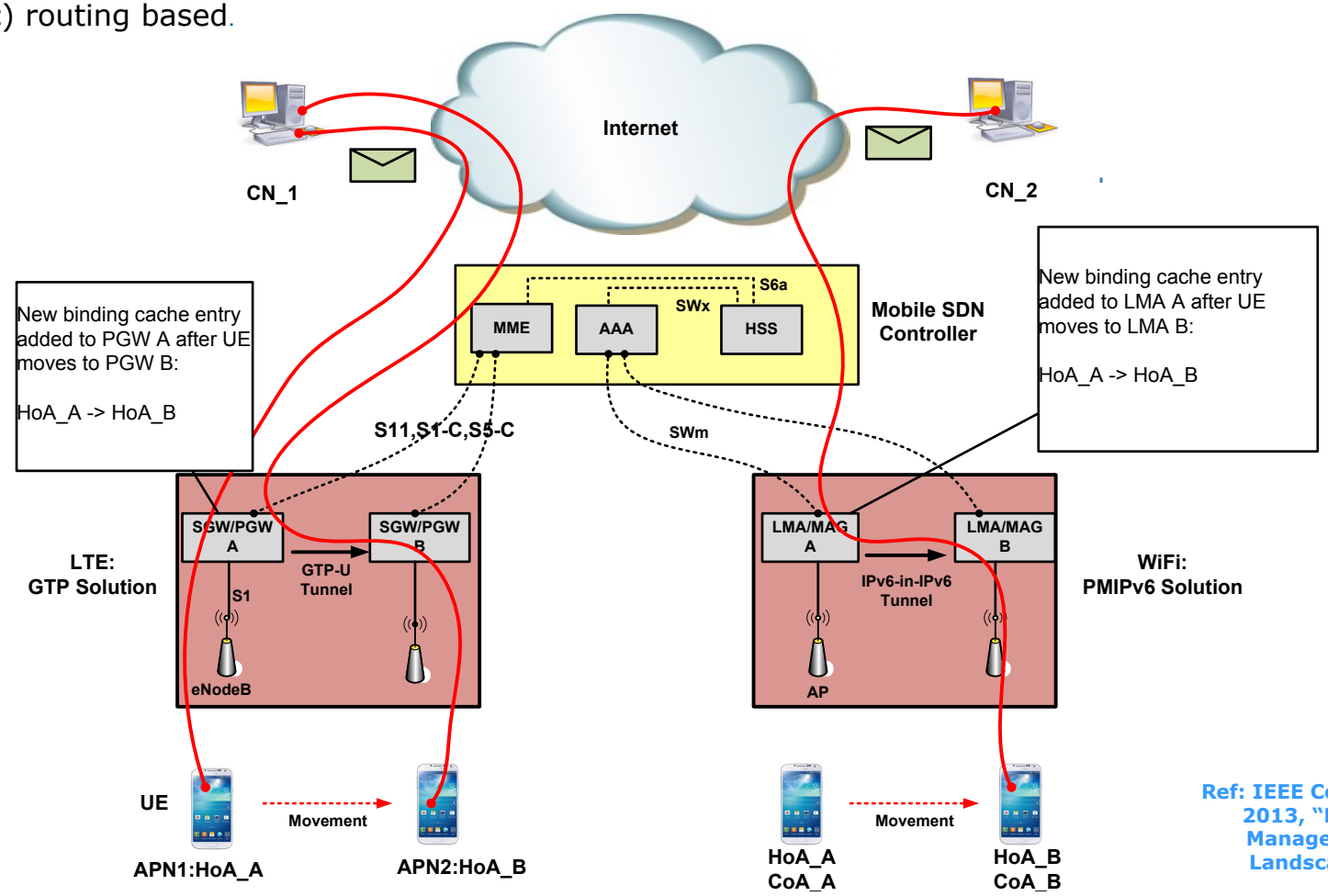
Ref: IEEE Comms Magazine, July 2013, "Mobile Flow: Toward SDN in Mobile Networks", K.Pentikousis et al

SDN in Mobile Networks – Applied View #2 Local Breakou



Distributed Mobility Management (DMM)

- In EPS, mobility management is based on either GTP or derivatives of MobileIP (DSMIPv6, PMIPv6, MIPv4 or v6). These are based on a centralised anchor point, which must remain the same for session continuity.
- DMM moves the control and user plane mobility anchor points closer to the edge and allows the UE to move between mobility anchors while still maintaining session continuity.
- DMM solutions are classified as either a) client-based b) network based (with full or partial distribution) or c) routing based.



Ref: IEEE Comms Magazine, March 2013, "Distributed Mobility Management: A Standards Landscape, J. Zuniga et al

The Long Term View of EPS

Long Term Multi-Tier Landscape

- Putting it all together….