March 2014

Executive Summary

Inside 3GPP Release 12: Understanding the Standards for HSPA+ and LTE-Advanced Enhancements

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The 3rd Generation Partnership Project (3GPP) standards are a major reason why the technology supports 6.4 billion mobile connections worldwide. The latest version, 3GPP Release 12 (Rel-12), arrives just as the mobile industry faces an unprecedented challenge: accommodating skyrocketing traffic growth amid a spectrum shortage that will not be alleviated until the next decade or further.

As Release 11 (Rel-11) standards were being finalized in late 2012, work began on 3GPP Rel-12. The primary goal of Rel-12 is to provide mobile operators with new options for increasing capacity, extending battery life, reducing energy consumption at the network level, maximizing cost efficiency, supporting diverse applications and traffic types, enhancing backhaul and providing customers with a richer, faster and more reliable experience.

In a kickoff workshop followed by subsequent 3GPP Radio Access Network (RAN) working group meetings, leading operators and equipment vendors discussed new proposals for interference coordination/management, dynamic Time Division Duplexing (TDD), frequency separation between macro and small cells, inter-site Carrier Aggregation (CA), wireless backhaul for small cells and more. The additional analyzed proposals for LTE multi-antenna and multi-site technologies were 3D Multiple Input Multiple Output (MIMO) and beamforming, as well as further work on existing Coordinated Multi-Point Transmission and Reception (CoMP) and MIMO specifications. Other items included support for Machine-to-Machine (M2M) applications, Self-Organizing Networks (SON) and interworking between HSPA, Wi-Fi and LTE.

Rel-12 provides enhancements in the three broad categories:

- LTE small cell and heterogeneous networks
- LTE multi-antennas (e.g., MIMO and beam forming)
- LTE procedures for supporting diverse traffic types (further work on HSPA+ was also included)

Rel-12 was initially developed on an 18-month schedule, with stage 1 completed or “frozen” in March 2013 and stage 2 frozen in December 2013. Recent deadline extensions pushed Rel-12 ongoing work to be ratified by September 2014, with Radio Access Network (RAN) protocols scheduled to be completed by December 2014 in a revised 24-month timeline.

This document provides an overview of Rel-12’s major features and how they benefit mobile operators and their customers. For additional details, see the full white paper, *4G Mobile Broadband Evolution: 3GPP Release 11 & Release 12 and Beyond*, on 4G Americas’ website.

REL-12 LTE-ADVANCED ENHANCEMENTS

Figure 1 summarizes how Rel-12 builds on the innovations in Rel-10 and Rel-11 to further increase performance, efficiency and capabilities. All three releases are also known as LTE-Advanced.

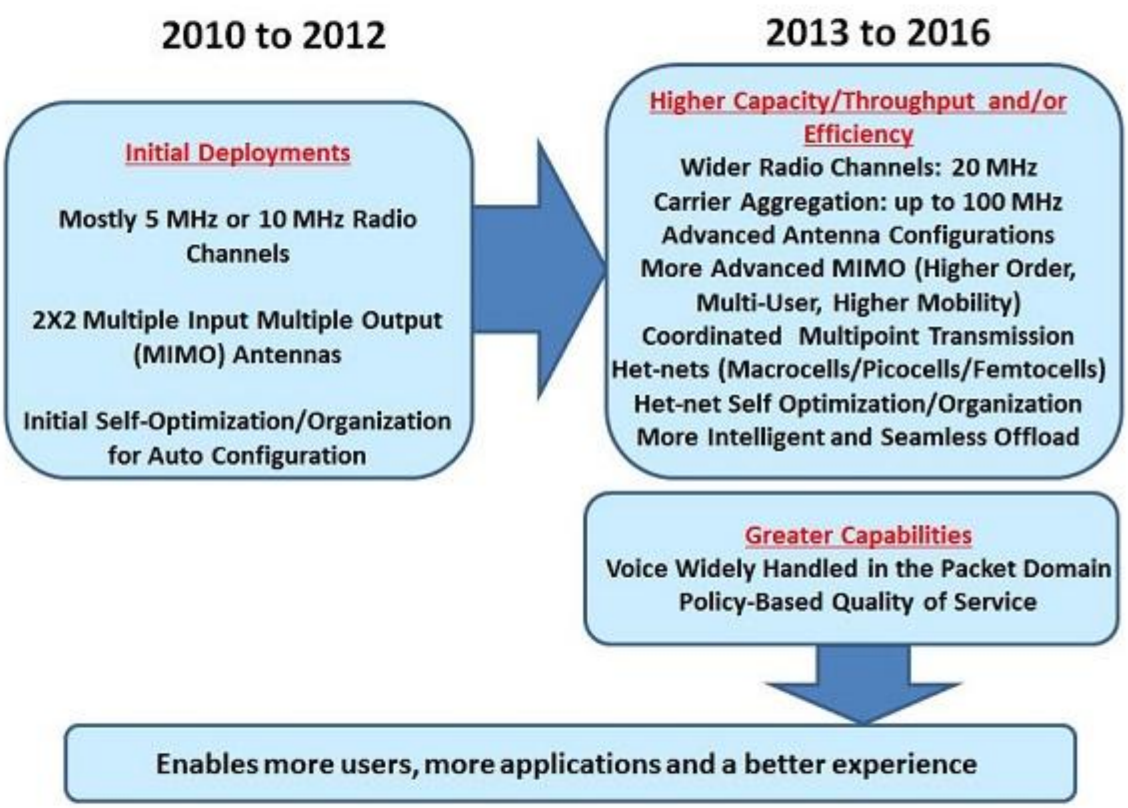

Figure 1: LTE as a Wireless Technology Platform for the Future.

Rel-12 defines new features and improvements to downlink enhancements for Active Antenna Systems (AAS) and MIMO, as well as small cells, femtocells, M2M, Proximity Services (ProSe), User Equipment (UE) enhancements, SON, Heterogeneous Network (HetNet) mobility, Multimedia Broadcast/Multicast Services (MBMS), Local Internet Protocol Traffic Offload/Selected Internet Protocol Traffic Offload (LIPTO/SIPTO), Enhanced International Mobile Telecommunications Advanced (eIMTA) and Frequency Division Duplex-Time Division Duplex Carrier Aggregation (FDD-TDD CA).

Active Antenna Systems (AAS)

AASs use flexible cell split (vertical or horizontal) and/or beamforming to provide increased system flexibility and performance. The AAS Base Station uses multiple transceivers on an antenna array to produce a radiation pattern that can be dynamically adjusted.

Spatial selectivity in both transmit and receive directions is important. For example, compared to fixed beam antennas, the AAS may experience different spatial selectivity because it does not achieve full spatial selectivity until after digital baseband processing of the multiple elements in the array. Another aspect is the requirement reference points at which core Radio Frequency (RF) requirements are specified. There are two main approaches: defining the requirements at the boundary of the transceiver or at the far field.

Downlink MIMO

Rel-12 features two Channel State Information (CSI) enhancements: 4Tx (Transmit) Precoding Matrix Index (PMI) feedback codebook enhancement and aperiodic feedback Physical Uplink Shared Channel (PUSCH) mode 3-2. The CSI enhancements enable the Evolved NodeB (eNB) to complete delivery of data packets earlier than with legacy CSI feedback, thus improving spectral efficiency. The Rel-12 4Tx codebook enhancement mainly targets cross-polarized antennas and thus, reuse of the 8Tx dual codebook structure. In addition to the enhanced codebook, a new aperiodic CSI feedback PUSCH mode 3-2 is introduced in Rel-12 with increased CSI accuracy since it provides both sub-band Channel Quality Indication (CQI) and sub-band PMI.

Small Cells

There are multiple types of small cell enhancements under consideration. A Physical Layer study seeks to improve system spectrum efficiency by increasing the transmission efficiency and/or reducing overhead. Mechanisms for efficient operation of the small cell layer that are being evaluated include interference mitigation and cell discovery.

The Higher Layer study focuses on mobility robustness, reducing the signaling load toward the core network due to handover, and improved per-user throughput and system capacity using dual connectivity. This refers to situations where a UE is capable of using radio resources provided by at least two different network points: a Master eNodeB and one Secondary eNodeB connected with non-ideal backhaul. Mobility robustness can be improved by keeping the control plane termination in a macro node, while allowing offloading of user plane traffic to pico nodes within the macro coverage. This solution also could reduce signaling overhead toward the core network by keeping the mobility anchor in the macro cell.

Rel-12 also has several femtocell enhancements, including mobility to shared Home eNodeB (HeNB), LTE X2 (Interface between eNBs) Gateway, low-cost and enhanced UE Machine Type Communication (MTC) operation in LTE, enhancements related to UE Power Consumption Optimizations (UEPCOP) and Small Data and Device Triggering Enhancements (SDDTE). The shared HeNB is shared by multiple operators and relies on the principle that the Public Land Mobile Network (PLMN) which is going to be used at the target side is selected by the source HeNB. The challenge is that the target PLMN selected must be compatible with the UE in terms of membership when that HeNB is hybrid/closed. Rel-12 enhances UE mobility procedures by adding the capability to read and report to the source eNB (prior to the handover decision) a list of acceptable PLMNs of the target cell. When receiving this new list and deciding to trigger the handover, the source eNB is also enhanced with the capability of verifying that it actually is an equivalent PLMN or the serving PLMN.

Increased data traffic leads to network densification which can include deploying multiple small cells, particularly numerous HeNBs, under each macro sector. This architecture creates a number of challenges for the scalability of X2 connections. Rel-12 enables scalability by letting an eNB connect to its neighbor HeNBs through one or more LTE X2 Gateways (X2GW). The feature remains backward-compatible in the sense that the peering connections can be either direct X2 or via the X2GW.

MTC/M2M

Rel-12 will enhance LTE-Advanced's ability to support MTC/M2M applications. One work item focuses on low cost and extended coverage. A study item is evaluating RAN solutions involving UE Power Consumptions Optimizations (MTCe-UEPCOP) and Small Data and Device Triggering Enhancements (MTCe-SDDTE). UEPCOP uses power saving (or dormant) state and extended Discontinuous Reception (DRX) cycle (idle and connected). SDDTE addresses data over Non Access Stratum (NAS) signaling over control plane, connectionless approaches over user plane and keeping UEs in connected mode for small data transmission.

Proximity Services

In ProSe communications, UEs that are near each other communicate directly rather than via the cellular network. The ProSe work in 3GPP is split into proximate discovery and direct communication. Rel-12 focuses on enabling direct broadcast communication between public safety personnel when a network is unavailable, such as following a disaster.

The ProSe discovery process identifies UEs that are near each other and enables operators to provide a highly power-efficient, privacy-sensitive, spectrally efficient and scalable proximate-discovery platform. It can either be direct or Evolved Packet Core (EPC)-level and is authorized by the operator. The network controls the use of resources used for discovery. The topics currently being studied as part of the discovery design in RAN 1 are signal timing, discovery signal design, payload definition, resource allocation and resource selection.

UE Receiver Enhancements

Cell densification, HetNets and the various MIMO types, all make UE receiver enhancements an ideal way to mitigate the increased inter-cell interference that comes as a natural consequence. Rel-10 was the first to define advanced UE receivers with interference cancellation and/or suppression. Rel-12 includes an ongoing Study Item that focuses on interference cancellation and/or suppression of data and control channels with possible network coordination.

Self-Optimizing Networks

Rel-12 enhances SONs by focusing on interoperability aspects of existing features while introducing additional features. This work includes evaluating different opportunities with more UE-specific handling, in light of release dependent requirements linked to the UE's capability to be served by a cell that is not the strongest cell (cell range extension). One example is the ping-pong handovers in the case of different treatment of various UE types and capabilities in two eNBs involved in load balancing. Another aspect concerns network deployments based on active antennas and the new needs for SON to manage the deployment, as well as the impact on existing SON features.

HetNet Mobility

This Study Item found that handover performance in HetNet environments is not as good as the macro-only environment in terms of handover failure and ping-pongs. Today, autonomous UE mobility state estimation is based purely on the number of experienced cell changes in a given time period, and the mobility state estimation may not be as accurate as in a macro-only environment.

The Mobility Enhancements Work Item aims to improve overall handover performance. Optimal configuration of parameters and better speed estimation are seen as potential solutions. Efficient small cell discovery is important to ensure efficient offload from macro to small cells while conserving UE battery life. Inter-frequency measurements required for accurate discovery of a small cell in another carrier not only use up battery power but also require measurement gaps. The Work Item aims at reducing UE power consumption requirements without sacrificing offloading potential.

Multimedia Broadcast/Multicast Services

Operators must have tools and processes for maintaining service when a node or interface fails. In Rel-12, MBMS enhancements extend these recovery schemes to cover all MBMS nodes and interfaces.

The first cornerstone of MBMS recovery mechanisms consists of re-establishing the MBMS sessions over the M3 interface following a Multi-Cell/Multicast Coordination Entity (MCE) failure or an M3 path failure. The feature can also re-establish MBMS sessions over the M2 interface following an eNB failure or an M2 path failure. The second cornerstone consists of the Mobility Management Entity (MME) takeover following a Spatial Multiplexing (SM) path failure. For example, when there is a permanent SM path failure, this feature enables the MBMS gateway to select an alternate MME from the pool.

Furthermore, although support of MBMS services has been introduced in Rel-9, there have been no UE measurements defined that could be reported to the network in order to help monitor the signal quality at the UE. In order to provide better tools for the network to monitor and adjust the MBMS operational parameters, new measurements targeting MBMS Single Frequency Network (SFN) signals will be introduced in Rel-12. Examples of radio layer Multicast Broadcast Single Frequency Networks (MBSFN) metric can include measurements related to signal strength, signal-to-noise ratio and error rate.

Local Internet Protocol Access and Selected Internet Protocol Traffic Offload

LIPA/SIPTO enhancements include the feature “Collocated SIPTO at local network.” This feature enables offloading of Internet traffic from the RAN node through an embedded Public Data Network Gateway (P-GW) function and into the private network. It also extends to a variety of RAN nodes, ranging from eNB to HeNB and NodeB+ to HNB. By directly offloading the Internet traffic into the private network, this feature significantly alleviates the core network’s workload, particularly for stationary or nomadic UEs.

The “SIPTO at Local Network with Stand-alone GTW” feature leverages the Rel-10 feature “SIPTO above RAN.” However, the Rel-12 feature has two main differences regarding location of the PGW enabling the offloading (in the private network) and the collocation of the Stand-alone (S-) and PGW. The set of RAN nodes served by a same gateway thus make up what is called a “Local Home Network” (LHN). This feature allows operators to offer a seamless offloading function for UEs moving within an LHN, while avoiding the single point of failure connectivity issue.

Enhanced International Mobile Telecommunications Advanced

LTE supports two different duplex modes: FDD and TDD. To better utilize spectrum in a TDD system, a TDD configuration that matches the traffic could be selected. This is the scope of the eIMTA work.

Most networks see more downlink (DL) than uplink (UL) traffic. As a result, they use a somewhat downlink-heavy configuration, which is driven by long-term network-wide averages. To enable better utilization of TDD resources, dynamic adaptation of uplink-downlink ratios is introduced in LTE Rel-12. To enable traffic adaptation, a UE is configured with two different TDD configurations from the network. The

UE then follows one configuration for uplink communication and a second configuration for downlink configuration.

Within Rel-12, 3GPP is working on procedures for allowing UEs to aggregate both TDD and FDD spectrum jointly. One solution to be specified is FDD TDD carrier aggregation between a number of TDD and FDD carriers. Aggregation between the FDD and TDD spectrum would allow user throughput to be boosted (at least for DL CA). It also would allow a better way to divide the load in the network between TDD and FDD spectrum.

Other use cases, other than CA for joint TDD and FDD operation, are also studied. For example, introducing support for dual connectivity between TDD and FDD. Dual connectivity provides a tool to connect UEs to cells that are operating either TDD or FDD while the cells are connected with a backhaul of higher delay than that required for CA. Potential reasons for operating in this mode include enhancing user throughput, lowering core network signaling or enhancing the mobility performance.

HSPA+ ENHANCEMENTS

Rel-12 defines multiple areas for enhancing HSPA which include UMTS Heterogeneous Networks, scalable Universal Mobile Telecommunication System (UMTS) FDD bandwidth, Enhanced Uplink (EUL) enhancements, emergency warning for Universal Terrestrial Radio Access Network (UTRAN), HNB mobility, HNB positioning for UTRA, MTC and Dedicated Channel (DCH) enhancements.

UMTS HetNets

To optimize performance in 3G small cell deployments, 3GPP is studying enhancements for UMTS HetNets, with a focus on improving their capacity. Options include boosting or tuning power control/Signal-to-Interference Ratio (SIR) for legacy networks and/or a new uplink pilot channel for enhanced HetNets, and methods that may minimize interference from UEs (not in Soft Handover (HO) between macro and so called low power node (LPN)) originating from UL/DL imbalance. One identified mechanism to achieve a simple and effective load balancing in HetNet deployments is to extend the coverage range of the Low Power Nodes (LPNs), referred to as "Range Expansion". The Rel-12 Study aims to evaluate system performance benefits of range expansion in combination with different multi-flow configurations, including co-channel and multi-carrier multi-flow configurations.

Scalable UMTS FDD Bandwidths

Rel-12’s ongoing work includes a feasibility standard study to identify options to support scalable UMTS FDD bandwidths smaller than 5MHz. There is one main identified solution, called “time dilation” (or time-dilated UMTS), which re-uses most of the legacy radio interface protocols structure. Another solution under initial evaluation is Scalable Bandwidth UMTS by filtering, which uses the same BB processing and the typical 3.84 Mbps chip rate used in UMTS FDD systems, filtering the signal to fit to a channel bandwidth below 3.84 MHz. Both proposals have the goal of giving operators more flexibility in how they use scarce spectrum resources.

EUL Enhancements

As each LTE and UMTS user drives more and more traffic, 3GPP has standardized several features to improve HSPA uplink and downlink performance. Rel-12 has identified eight additional Enhance Uplink (EUL) enhancements to study: enabling high user bitrates in a mixed-traffic scenario, rate adaptation to support improved power and rate control for high rates, improvements to handling of dynamic traffic on EUL, improvements to EUL coverage for both single and multi-Radio Access Bearer combinations, a more efficient approach for UTRAN in case of uplink overload, reducing UL control channel overhead for HSPA operation, mechanisms to perform UL data compression between the UE and the RAN, and low-complexity uplink load-balancing solutions.

Emergency Warnings for HNBs

UMTS Cell Broadcast does not support the concept of warning areas. Rel-12 includes a study into solutions for handling Emergency Warnings for HNBs, such as the introduction of an Emergency Area ID list similar to what LTE supports.

Additional HNB Mobility enhancements include: Cell Forward Access Channel (CELL_FACH) and Cell Paging Channel (CELL_PCH) and UTRAN Registration Area Paging Channel (URA_PCH) support for HNBs. This is achieved by introducing a method for managing the User Radio Network Temporary Identifiers (URNTIs) where the HNB-GW allocates blocks of URNTIs by specifying a URNTI prefix to each HNB under its control, enabling these modes to be supported for Rel-12 HNBs.

DCH Enhancements for UMTS

UMTS and HSPA radio access protocols include two main types of transport channels to carry traffic over the UTRAN radio interface: DCH, used for transporting Circuit-Switched (CS) (and Rel-99 Packet-Switched (PS)) traffic and the shared HSPA channels, used to carry high-speed data. Rel-12 includes work to enhance link efficiency in UMTS. A Study Item showed that optimizing Dedicated Channel (DCH) efficiency will provide benefits not only to CS traffic capacity, but also PS/data capacity.

In fact, a few of the optimizations were shown to provide data throughput gains in scenarios involving a mix of voice and data transfer when circuit-switched voice is carried over DCH. These optimizations are DCH Frame Early Termination and UL/DL Overhead optimization. These can improve the UE battery life (or talk time) as well. Based on the outcome of the study, 3GPP is in the process of specifying DCH enhancements in Rel-12.

NETWORK AND SERVICES ENHANCEMENTS

Rel-12 includes features for network and services enhancements for MTC, public safety, Wi-Fi integration, system capacity and stability, Web Real-time Communication (WebRTC), further network energy savings, multimedia and the Policy Charging Control (PCC) framework.

MTC and Other Mobile Data Applications Communications Enhancements

A third release of improvements is being developed for MTC devices and smartphone data applications under “Machine-Type and other mobile data applications Communications Enhancements (MTCe)”. The two main building blocks are device-triggering enhancements and Small Data Transmission (infrequent and frequent) (SDDTE) and UE power consumption optimizations (UEPCOP).

Small data transmission may also cause the UE to transition frequently between an idle and connected state if the UE is sent to idle mode soon after transmission is complete. Such frequent transmissions can have adverse effects on the network and the UE. One solution considered in 3GPP is to keep the UE in Radio Resource Control (RRC) connected mode for a long(er) time to reduce state transition and to assign a long Discontinuous Reception (DRX) cycle for the connected mode to ensure battery consumption is not negatively impacted. Finalization of the work has RAN dependencies, and SA2 will align its specifications dependent on conclusions reached by RAN. 3GPP also agreed to introduce power-saving state for devices.

Public Safety

LTE enhancements for public safety are widely backed by governments around the world and studied by 3GPP with Proximity Services (ProSe) and Group Call System Enablers for LTE (GCSE_LTE).

Proximity services (ProSe) for support of public safety needs to support four capabilities: discovery of users who are in close physical proximity and wish to have direct communications, facilitating direct communications between users with or without supervision from the LTE network, ability for a mobile device to function as "User Equipment to Network Relay" for another mobile device which is outside of the network coverage area and ability for a mobile device to function as "User Equipment to User Equipment Relay" between two other mobile devices which are out of direct communication with each other.

Group Communication System Enablers will optimize the LTE environment where simultaneously communicating with multiple users is needed. Group Communication Service is expected to support, voice, video, or more general data communication. Still under consideration is how much group communications and Push-to-Talk (PTT) functionality should be incorporated into the LTE infrastructure, versus how much of this functionality should be delivered by non-standardized application servers. The use of these application servers may allow the different public safety organizations or regions to have the capability to customize the system operations to their specific needs and situations.

Wi-Fi Interworking

Many mobile operators are using or considering to use Wi-Fi as a way to complement their cellular networks, such as by offloading traffic to Wi-Fi in places where cellular spectrum is extremely scarce. Wi-Fi interworking with 3GPP technologies is already supported at the Core Network (CN) level. However, as operator-controlled Wi-Fi deployments become more common and Wi-Fi usage increases, there is a need for RAN-level enhancements for Wi-Fi interworking that improve user experience, provide more operator control and enable better access network utilization.

Rel-12 focuses on solutions enhancing mobility between LTE/UMTS and Wi-Fi for access points deployed and controlled by cellular operators and their partners. The Rel-12 feasibility studies on Wi-Fi cellular interworking have three objectives:

- Identify solutions that enable enhanced operator control for Wi-Fi interworking and enable Wi-Fi to be included in the operator's cellular Radio Resource Management (RRM).

- Study enhancements to access network mobility and selection that account for information such as radio link quality per UE, backhaul quality and load for both cellular and Wi-Fi access.

- Evaluate the benefits and impacts of identified mechanisms over existing functionality; including core network-based Wi-Fi interworking mechanisms (e.g., Access Network Discovery and Selection Function (ANDSF)) ensuring that such benefits cannot be solved using existing standardized mechanisms.

Three potential Wi-Fi interworking solutions were discussed in 3GPP Rel-12, but none were approved by the end of 2013.. Separately, an optimized offloading feasibility study assessed potential issues with features defined in previous releases for WLAN offload. The aim was to optimize the procedures for offloading traffic to WLAN from 3GPP (Access Networks (ANs) and to improve network and interface selection for this traffic.

Core Network Signaling Overload

Several areas for system capacity and stability were studied in Rel-12, with one reaching completion: Core Network Signaling Overload. The original focus was Home Location Register (HLR) overload scenarios that could result from any of a number of causes, such as Radio Network Controller (RNC) failure or restart, or Denial of Service attacks. The Core Network Overload Solutions study (FS_CNO) began in Rel-11 and has three threads in Rel-12. One of them addresses a scenario where a massive number of users simultaneously induce User Location Information (ULI) update notifications, such as in business districts, which may cause an excessive signaling load within the PLMN. Three solutions are under study.

WebRTC and VoIP

WebRTC enhances Web browsers with support for Real-Time Communications (RTC) capabilities via JavaScript Application Programming Interfaces (APIs), enabling smartphones to serve as video conferencing endpoints. Rel-12 is developing specifications for clients to access the Internet Protocol (IP) Multimedia Subsystem (IMS) services using WebRTC. The architecture study involves developing support for IMS media (including transcoding) and protocol interworking necessary for a WebRTC client to access IMS services including charging, Quality of Service (QoS), authentication and security.

The 3GPP SA4 working group specification is developing multimedia services, codecs and protocols. In Rel-12, SA4 is developing a new Voice over Internet Protocol (VoIP) codec that improves speech quality and enables operation at lower data rates. Other work includes investigating using the High Efficiency Video Coding (HEVC) codes to improve performance and developing features and enhancements for MBMS, such as multicast-on-demand.

Network Energy Savings

Rel-12 introduces techniques for improving network power efficiency, CO2 emission and operating expenses. This includes the mechanisms for cell switch-on in intra-LTE overlaid scenarios that may be UL-based (Internet of Things (IoT) measurements or Sounding Reference Signal (SRS) detection by the eNB), or DL-based (probing).

Policy and Charging Control

Rel-12 introduces system enhancements on top of the existing Policy and Charging Control (PCC) framework to fulfill application-based charging for the detected applications. In the case of the Traffic Detection Function (TDF), system enhancements are needed so that the applications can not only be detected and enforced but also be charged by the TDF. Time Based Usage Monitoring is also added on top of the Rel-11 volume-based usage monitoring.

RELEASE-INDEPENDENT FEATURES

As the spectrum allocations in different countries evolve, 3GPP continuously updates and adds new frequency bands. While a new frequency band, carrier aggregation scheme or other enhancements may be introduced in a particular release, it may be used in UEs that support an earlier release. This approach speeds the utilization of new spectrum and allows terminal manufacturers to support various frequency bands without having to otherwise upgrade all the terminal's features to the latest release level.

Rel-12 adds four bands, with another three under consideration. Aggregated over all releases, and assuming that the three bands are completed, Rel-12 brings the total up to 43 bands identified for UTRA/EUTRA, as tabulated in Appendix A in the full white paper. Typically, about three bands are added each year.

CA combinations are being added even more quickly. In 2012, there were only 21 CA schemes. In 2013, there were 13 intra-band and 50 inter-band configurations, an indication of the explosive demand for spectrum and the demand for increasing the typical end user's peak throughputs. The additional presence of combinations of a single UL with three DL carriers reflects the overwhelming preponderance of DL traffic in today's typical wireless data network and the need for additional DL capacity to serve it. This ability to serve typical traffic patterns with appropriate combinations of UL and DL blocks of spectrum is a major appeal of CA and is driving the rapid adoption of this capability.

Based on the latest updates, all work on Rel-12 is scheduled to be finalized by December 2014, when the RAN protocols in Stage 2 are completed. Shortly thereafter, 4G Americas will publish an updated version of this executive summary on Release 12.