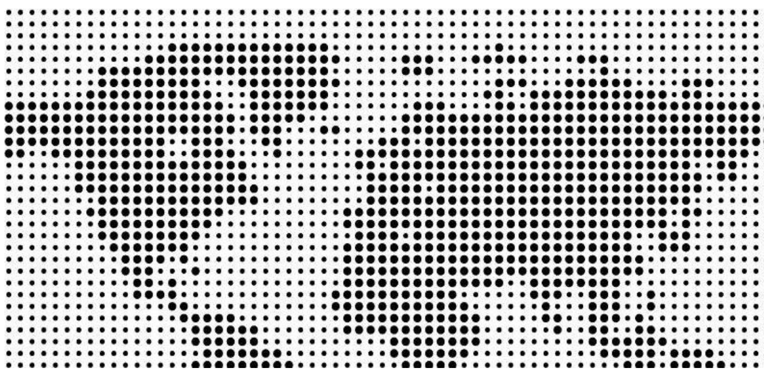
A 3G/LTE Wi-Fi Offload Framework: Connectivity Engine (CnE) to Manage Inter-System Radio Connections and Applications



Qualcomm Incorporated
June 2011

QUALCOMM Incorporated
5775 Morehouse Drive
San Diego, CA 92121-1714
U.S.A.

A 3G/LTE Wi-Fi Offload Framework: Connectivity Engine (CnE) to Manage Inter-System Radio Connections and Applications

Table of Contents

Executive Summary

The ever-growing consumption of data by mobile device users has put a strain on mobile networks. Operators are attempting to address the challenge by upgrading their wireless WANs and deploying femtocells. However, in some scenarios, even these measures may not be adequate.

With an increasing number of mobile devices featuring Wi-Fi capabilities and Wi-Fi access becoming more widely available in homes, enterprises and retail locations, Wi-Fi offload is emerging as an attractive option for network operators.

Operators would benefit most from seamless Wi-Fi offloading by applying it to data traffic that requires best effort and low quality of service (QoS). An ideal offload solution should provide users with a seamless experience while they use various applications on their devices. It should also make intelligent decisions about keeping data flows on preferred networks (e.g., keep some traffic, such as VoIP, on 3G/LTE even when Wi-Fi is available). It should optimize the resources on the mobile device such as battery life in addition to optimizing the user experience.

Current solutions to solve data offload problems are simple, proprietary, and do not provide a comprehensive and flexible solution as such described above.

For operators to successfully leverage a Wi-Fi offload solution, we believe that three essential components must exist within the solution:

- A mechanism to provide operator’s policy for unplanned networks to the device in a dynamic fashion
- Algorithms in the device to detect characteristics of unplanned Wi-Fi networks and determine the best possible use of available networks
- A Mechanism to allow seamless handovers between 3G/LTE and Wi-Fi

Together, these three components make up the framework for Qualcomm’s Connectivity Engine (CnE).

This paper discusses smart algorithms in the device needed for further improving data traffic management and network selection based on the principles described above

using Qualcomm’s CnE. In addition, it also discusses the 3GPP evolution of operator’s policies and seamless mobility related to Wi-Fi offload.

[1] Introduction

Current offload solutions present challenges to operators due to various limitations such as:

- Identifying different types of Internet traffic in order to select appropriate traffic for offload
- Applying specific policies for specific types of traffic to maximize available resources and user experience

Current solutions send all the traffic to Wi-Fi when available and only some check Internet connectivity. However, none of these solutions consider other metrics. From the device perspective, the solutions view Wi-Fi as being available even if it may be unusable, which results in a poor user experience.

In another scenario, if an application that's streaming video freezes when a 3G/LTE to Wi-Fi offload occurs, users may restart the application or they may turn off their Wi-Fi radio and never turn it back on. In such cases, operators lose the ability to offload capacity for users because of a poor user experience.

Heterogeneous mix of Wi-Fi and 3G/LTE requires smart device management for seamless connectivity.

Wi-Fi offload decisions based solely on signal strength may also be less than optimal in many situations. For example, a Wi-Fi network with "excellent" signal strength may be suffering backhaul congestion or may be blocked by a firewall.

In any one of the aforementioned cases, mechanisms that make intelligent offload decisions would greatly enrich the user experience. Qualcomm's CnE is a framework of algorithms used for improving system selection based on operator *preferences* and local UE *conditions/actions* consistently across devices. A CnE based offload solution enables operators and OEMs to define how radios and applications are managed in a multi-radio environment. In addition, device management in the network done via the Open Mobile Alliance Device Management (OMA DM) server allows for dynamic updates of framework parameters and functions.

We have identified three components within the CnE framework to address the offload problems mentioned above. These three components are:

- A dynamic mechanism to implement operator policies

- A method to detect optimal Wi-Fi characteristics besides signal strength
- A mechanism to allow seamless handovers

Qualcomm's CnE based on these three components can increase mobile device performance and provide a seamless user experience.

[2] Qualcomm's CnE Components

2.1 Mechanism to provide Operator's Policy

Operator policies can help optimize network capacity by balancing the traffic load during peak times or at specific locations where traffic load is higher than average. These policies manage data offload in dynamically changing environments. Qualcomm's CnE uses 3GPP standard based operator policies as one of its three components mentioned above.

Without having policies that can act on different traffic types, operators cannot intelligently choose which traffic to route to which network. The Access Network Discovery and Selection Function (ANDSF) framework was introduced first in 3GPP Release 8 to standardize operator policy mechanism and since then it has evolved in the standard to provide further enhancements like flow mobility and more specific traffic identification.

2.1.1 3GPP Release 8

In Release 8, the ANDSF framework provides access network information; for instance, leveraging Wi-Fi Access Points in the vicinity of the UE location, to enhance the way the UE discovers new non-3GPP Access Networks. It also provides mobility policies in order for the operator to guide the UE to select the proper radio technology in any given location at any given time.

Release 8 does not allow simultaneous connections to multiple access networks. For this reason, the Inter System Mobility Policies (ISMPs) were defined independent of the traffic sent by the UE. For example, when a device discovers the presence of Wi-Fi, all the traffic must be offloaded to Wi-Fi or all the traffic must stay on 3G, regardless of what type of traffic is being generated by the applications running on the device.

2.1.2 3GPP Release 10

In Release 10, simultaneous network connections to multiple radio access technologies were enabled by Multi Access PDN Connectivity (MAPCON), IP Flow Mobility (IFOM) and non-seamless Wi-Fi offload [1]. To take this into account, the ANDSF framework has been enhanced with the introduction of Inter System Routing Policies (ISRP), allowing the operator to provide policies based on the traffic exchanged by the UE.

In this way the operator can indicate preferred or forbidden radio access technologies as a function of the type of traffic the UE sends. Specifically an ISRP can be based on:

- the PDN identifier (i.e. Access Point Name or APN) the UE uses for a given connection,
- the destination IP address the UE sends traffic to,
- the destination port number the UE connects to, or
- a combination of the above three elements.

Operators can benefit significantly if they can identify a subset of traffic which has specific characteristics

Figure 1 shows an example set of ISRPs that could be provided by an operator to the UE:

Policy	Traffic Description	Rule Priority	Preferred Radios	Forbidden Radios
1	Destination Port = 2568	2	3GPP	Wi-Fi
2	Destination IP Address = 74.225.124.0/24	1	Wi-Fi with DSMIPv6 3GPP	
3	Destination Port = 80	5	Non seamless Wi-Fi 3GPP	
4	APN = “Internet”	3	Wi-Fi with DSMIPv6 3GPP	
5	APN = “Internet” AND Destination Port = 7654	2	3GPP	Wi-Fi

Figure 1: An Example of 3GPP Release 10 ISRPs.

The example shows how an operator policy can be as simple as policy #1 where it is only checking the destination port to determine if traffic should only be allowed on 3GPP – for example, VoIP data traffic. And the same framework allows an operator to define a more complicated policy such as policy #5 where two parameters – the Access Point Name (APN) *and* the Destination Port can be combined in a logical AND function to come up with a custom policy.

In recent years a clear trend of aggregation of the Internet traffic into few transport ports has emerged. Fewer and fewer ports carry most of the Internet traffic and in particular a very large amount of the Internet traffic is carried over *port 80* (HTTP). Recent data shows that more than 50% of the total Internet traffic is carried over port 80 of various types such as web browsing, video streaming, email, and application data.

These trends impact the 3GPP Release 10 ANDSF and ISRP framework discussed in the previous section. For example, the operator with the current framework is not able to discriminate between video streaming (e.g., www.youtube.com) and web browsing (e.g., www.google.com). As another example, the operator will not be able to set different policies for different applications downloaded by a mobile device from an application store unless they are designed to use different port numbers.

2.1.3 3GPP Release 11

Given the limitations analyzed in the previous section, there is a need to more clearly identify the traffic to which a given ISRP applies.

Operators can benefit significantly if they can identify a subset of traffic which has specific characteristics (e.g., video streaming) but shares the same port number characteristics of other types of traffic (e.g., port 80 for HTTP traffic).

Some ways of identifying traffic independent of destination IP and port are:

- **IP flow throughput**. All IP flows that generate more than a given throughput threshold (e.g., 1 Mbps) should be handled in a certain way (e.g., Wi-Fi preferred).
- **File size**. In some situations a file download is anticipated by a protocol where the file size of the download is provided by the server to the client. FTP is an example of this case, but some podcast synchronization applications which run over HTTP have this property as well. In this case, it could be possible for the operator to guide the UE to download (or upload) large files only in a given network or location.
- **Application name or identifier**. The name or an identifier of the application which generates a given IP flow can be used to identify the traffic. This cannot be a general solution which applies to all applications but can be used by well-

known applications or operator-provided applications (e.g., an audio streaming application which is pre-loaded in an operator phone).

- **Role identifier**. Similarly, an abstraction of the characteristics of the application could be used. We refer to it as the "role" of the application and can be, for example "VoIP," "Video Streaming," etc. This role can be either inferred by the entity in the UE which enforces the routing decision or can be provided via an API by the application.
- **FQDN**. Instead of using the destination IP address, the destination FQDN can be used. This would allow a simpler configuration and would allow having a common set of policies even in case there are a set of distributed web servers (CDNs).

In 3GPP Release 11 there is ongoing study of these methods to identify traffic and the goal is to standardize them and make them available across platforms such as Qualcomm's CnE [2]. It should however be noted that some of these ideas can already be implemented by operators. The CnE can organize these policies in a hierarchy. For example, a priority order among multiple policies determines which policy is applied with the highest priority.

The inter system mobility and routing policies delivered to UE, or pre-configured on the UE, have different validity conditions. The validity of a policy takes into account roaming, location, and time of day [3]. A policy becomes valid when all three validity conditions match. For example, a certain policy may apply to the UE while it is not roaming, it is in a specific location, and the time of day indicates evening while another policy (or no policy) may apply to the UE while it is roaming, or the time of day is morning.

These methods give operators more control on when they want to offload specific types of traffic. They can optimize their network and load balance the data usage. The CnE allows their policies to be dynamically adapted to make intelligent offload decisions based on the user's environment.

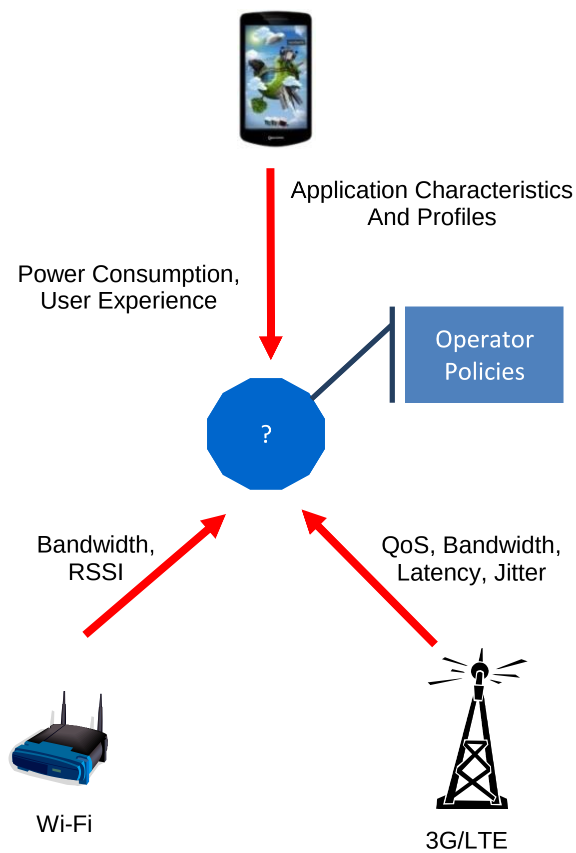
2.2 Algorithms in the device to detect characteristics of unplanned Wi-Fi networks

Traditionally, 3G/LTE cellular networks have been well planned. Operators spend a lot of time and resources carefully planning their networks so that they provide the best possible combination of coverage and capacity.

Contrary to cellular networks, the majority of Wi-Fi hotspots are unplanned, and access points appear and disappear dynamically. Coverage and capacity is not consistent. For data offload to Wi-Fi, it is important to detect the characteristics of these unplanned Wi-Fi networks so that Qualcomm's CnE can offload to Wi-Fi only under those conditions in which the user experience is not compromised, and Wi-Fi becomes a seamless extension of the cellular network. The CnE algorithms used together with the Wi-Fi offload evolution in 3GPP form an excellent solution for operators.

The goal of a smart connectivity engine should be to select the best interface for any given application. To achieve this selection, the engine has to evaluate the characteristics of the link/path per interface in terms of bandwidth, latency, round trip time, Internet connectivity, etc. For example if a UE is at the edge of coverage for Wi-Fi, then preference can be given to 3G/LTE over Wi-Fi. In addition, the engine has to know the requirements of the application like the required/desired throughput and required latency. Qualcomm's CnE does all the above.

Qualcomm's CnE is context aware as it runs in the device. It takes actions based on UE states such as battery level, location, and other conditions as shown in Figure 2. It can also maintain session continuity and mobility by optionally including advanced schemes such as the use of Dual Stack Mobile IP (DSMIPv6) and IP Flow Mobility



Context aware solution enables seamless connectivity.

(IFOM).

Figure 2: Context Aware CnE

Qualcomm has identified three metrics to measure network characteristics: 1) Channel Quality Estimate (CQE). 2) Backhaul Quality Estimate (BQE). 3) Internet Connectivity Detection (ICD). Qualcomm's CnE relies on these three metrics as inputs and combines them with other available information, such as the UE battery level, to intelligently detect and select the best interface for any given application.

2.3 A mechanism to allow seamless handovers between 3G/LTE and Wi-Fi

It is important for operators to provide a seamless user experience in their data offload solution to keep the users satisfied and avoid churn. Sudden disruptions in applications, such as those that happen when using existing offload solutions in an unplanned Wi-Fi environment, lead to poor user experiences. The primary reason these sudden disruptions occur is because existing solutions use a break-before-make switch between Wi-Fi and 3G/LTE, which certain applications can not handle gracefully.

3GPP Release 10 has specified the use of DSMIPv6 for IP Flow Mobility. Qualcomm's CnE is capable of optionally using DSMIPv6 [4] to ensure a smooth handover that works in a make-before-break manner. The CnE interface selection takes into account many scenarios before making a final decision to determine which interface is best suited for a given application, and how to make a seamless handover if an interface change is required.

DSMIPv6 can provide an optimal solution for seamless Wi-Fi offload.

For example, if a user is watching a video on her UE over Wi-Fi in her office, and she starts walking toward the parking lot, Wi-Fi coverage could change very quickly. The CnE would detect this condition and determine that the best interface for this video application is 3G/LTE after the user enters the parking lot. It is now the job of the CnE to make this switch from Wi-Fi to 3G/LTE in such a seamless manner that the user does not experience any break in the video. This can be achieved by using DSMIPv6 which was standardized in 3GPP Release 10. DSMIPv6 allows seamless handovers which are robust and allow make-before-break connections for a better user experience. Some applications cannot survive the IP address changes. This is not the case with CnE when it is using DSMIPv6 which preserves the IP address, enabling applications to run without disruption.

An alternate example of the same scenario would be Qualcomm's CnE deciding that when a user is in a Wi-Fi hotspot and in 3G/LTE coverage simultaneously, an operator policy prioritizes the use of Wi-Fi for watching a video. However, the CnE – which monitors the backhaul and network efficiency – determines that the Wi-Fi network is too congested, it would route the video IP Flow to 3G/LTE to ensure a better user experience.

The mechanism that provides seamless handovers between 3G/LTE and Wi-Fi is an important part of Qualcomm's CnE. This mechanism in itself is a tool and this tool, when utilized effectively by the CnE results in a powerful offload solution that operators can deploy to leverage Wi-Fi as a seamless extension to their 3G/LTE networks.

[3] Conclusion

Mobile data traffic consumption is increasing exponentially. Since Wi-Fi is widely available at home and through various hotspots, and is also in a number of 3G/LTE devices, it offers the potential to become a seamless extension of 3G/LTE. Wi-Fi offload solutions available today provide basic features. Operators can leverage Wi-Fi offload to manage network capacity in a more convenient manner with Qualcomm's CnE.

Qualcomm's CnE enables improved system selection by implementing operator policies for:

- efficient capacity management
- improvements in user experience through seamless handovers
- longer battery life by making intelligent decisions
- support for simultaneous 3G/LTE and Wi-Fi access

If operator policies for unplanned Wi-Fi networks can be dynamically provided to devices, which can detect key characteristics of unplanned Wi-Fi networks, then such devices can make smart decisions based on the policies and network characteristics and then seamlessly offload selected IP flows.

An offload framework based on Qualcomm's CnE offers all of the benefits mentioned above under operator direction and are based on the local UE operating environment. This solution offers simple and standardized implementation to operators that want to better utilize their assets.

[4] Glossary

3GPP	Third-Generation Partnership Project
ANDSF	Access Network Discovery and Selection Function
APN	Access Point Name
CDN	Content Delivery Network
CnE	Connectivity Engine
DSMIPv6	Dual Stack Mobile IP v6
FQDN	Fully Qualified Domain Name
HTTP	Hypertext Transfer Protocol
IFOM	IP Flow Mobility
ISMP	Inter System Mobility Policy
ISRP	Inter System Routing Policy
LTE	Long Term Evolution
MAPCON	Multi-Access PDN Connectivity
OEM	Original Equipment Manufacturer
OMA-DM	Open Mobile Alliance Device Management
PDN	Packet Data Network
QoS	Quality of Service
RSSI	Received Signal Strength Indication
UE	User Equipment
VoIP	Voice over IP

[5] References

[1] 3GPP TS 23.261 v10.1.0 (2010-09), “IP flow mobility and seamless Wireless Local Area Network (WLAN) offload; Stage 2”.

[2] 3GPP TR 23.855 v0.1.0 (2011-04), “Data identification in ANDSF”.

[3] 3GPP TS 24.312 v10.2.1 (2011-04), “Access Network Discovery and Selection Function (ANDSF) Management Object (MO)”.

[4] 3GPP TS 23.402 v10.3.0 (2011-03), “Architecture enhancements for non-3GPP accesses”.