1.0 EXECUTIVE SUMMARY

With advent of IP capable smart devices e.g. mobile phones, tablets etc. and easy internet access, there has been an exponential growth in data traffic. Cellular network operators have been trying to cope up with this ‘tsunami’ of data traffic by adopting new technological innovations like LTE. But it’s pretty much clear that Shannon’s channel capacity will hold true in the end and cellular network shall create a bottle neck against this rise in data demand. Also, as the cellular spectrum is a scare resource and is licensed, allocating more spectrums to meet data demands won’t be a business viable solution either.

This is where WiFi (WLAN) networks come to the rescue of network operators. Idea is to offload, on-the-fly, some or all of the data traffic from cellular network e.g. GSM, LTE etc. to Wi-Fi network. This should happen in a seam-less fashion so that: (a) subscriber is not required to intervene, say for authentication; (b) data traffic should not stop when this handover happens.

2.0 WHY WI-FI?
Following factors augment the choice of Wi-Fi as an alternate technology for offloading cellular data traffic:

1. Research shows that around 80% of the mentioned data traffic happens when subscribe is stationary (i.e. not mobile) e.g. with-in a building, house, office compound, malls etc. Thus mobility is not even required here.
2. Now-a-days, almost all of the smart devices come with Wi-Fi support. So no additional cost is required from subscriber perspective.
3. Wi-Fi networks have low cost and are everywhere.
4. Wi-Fi spectrum is not licensed and is re-usable.

Thus Wi-Fi becomes an obvious choice for network operators. It can help improve cellular coverage and increase capacity through spectrum reuse in areas where most of the data traffic is being generated e.g. in a building. Thus cellular network shall be used for high QoS intensive traffic as well as mobility requirements e.g. VOIP, where as Wi-Fi shall be used for low QoS data traffic e.g. downloads, web surfing etc.
3.0 CHALLENGE WITH WI-FI OFFLOAD
Existing Wi-Fi networks offer following challenges to LTE <-> Wi-Fi offload:
- Un-Trust ed access points (those which are not owned by cellular service providers) don’t provide secure connection to EPC
- Existing APs don’t provide a means to authenticate with core network using cellular network credentials e.g. SIM (GSM), USIM (LTE) etc.
- Existing APs don’t provide a means to obtain same IP Address (as obtained via LTE network) via Wi-Fi network
- Existing Wi-Fi networks don’t facilitate a means to UE by which they can select an AP which can provide them connectivity to core network of their server provider.

4.0 LTE WIFI COEXISTENCE
Advances in 802.11 and 3Gpp have provided mechanisms for operators to deploy a mixed network of LTE nodes and WiFi access points, connected to a common core.

![Figure 1 Combined LTE WiFi Network Architecture](image)

UE is connected to both UTRAN and WiFi. WiGW (WiFi gateway) offers secure connectivity from untrusted WiFi access to PDN gateway. PDN gateway acts as anchor point for mobility between the two access networks.

4.1 Mechanisms

4.1.1 LTE – To – WiFi Handover

Following sequence of events happen:
- UE is already connected to an LTE network.
- UE detects available Access-Points (Hot-Spots) and using 802.11u specification, it chooses the one which can provide connectivity to its subscriber (Network provider). 802.11u enhances Beacon/Probe Request/Response management frames with interworking specific information e.g. if internet connectivity is available or not, list of roaming consortiums etc. Also, using ANQP/GAS request/response mechanism, UE can seek more information e.g. list of NAI values from AP (or
information servers sitting behind AP) before getting associated with it; thus enabling it to make more informed decisions prior to association.

- UE automatically initiates authentication sequence using cellular network credentials e.g. EAP-AKA or EAP-SIM (without requiring user to enter any credentials). This authentication involves UE, AP, WiGW (WiFi gateway) and subscriber network (AAA server and PDN GW).
- Once authentication is successful, UE initiates DHCP sequence by sending discover message. WiGW receives this request and in-turn initiates GTP (or PMIP) tunnel creation with PGW at the end of which (if successful), PGW provides same IP address to WiGW which in turn offers it to UE via WiFi network.
- On receiving the same IP address, as that of LTE network, from WiGW, replies back with DHCP ACK. This lets PGW trigger a NAS Detach message for LTE connection.
- The moment UE receives a network detach, it starts redirecting the already running IP traffic towards Wi-Fi network; leading to successful LTE to WiFi handover.
- This results in seamless handover because:
  - It doesn’t require user intervention
  - It uses same cellular network credentials for automatic authentication e.g. USIM or SIM
  - It obtains same IP address, as received in LTE side, from Wi-Fi side. Thus applications don’t even come to know about this handover.

4.1.2 WiFi – To – LTE Handover
- UE is already connected to WiFi network and IP traffic is running.
- UE decides to move back to LTE network and sends a connection request to LTE network
- Once LTE PDN becomes active, it starts sending traffic back to LTE network
- Once traffic starts flowing towards LTE network, UE brings down the WiFi connection.

5.0 FUTURE EVOLUTION TO IFOM
The approach discussed so far provides a mechanism for seamless handover between WiFi and LTE networks; however it imposes the restriction of using either of the two networks at a point of time. IP Flow Mobility (IFOM) enhances the capability further by allowing simultaneous connection to both WiFi and LTE network (in fact, any macro cellular network with a packet bearer) - with simultaneous IP flows over the two accesses. IFOM is being defined as part of Rel 12 of 3GPP.

![Figure 2 IFOM in LTE-WiFi networks](image-url)
The key step in the evolution to IFOM is to completely separate the flow management from the access network; once IFOM is deployed, any macro network, starting from Greenfield LTE to Wifi to GPRS. The entire intelligence of simultaneous attachment to different networks and the mapping of flows to individual networks is at the endpoint, in keeping with standard 3gPP goals. In order to support this, the terminal IP stack will have to be upgraded to DSMIP (Dual Stack Mobile IP), which is a new IETF standard [RFC 5555]. On the network side, the home agent will also have to support the equivalent DSMIP. The IFOM architecture will be a radical departure from LIPA/SIPTO and other standard forms of offloading; there is no ‘break out’ point within the access network, where the IP data is separated. Instead, the terminal itself splits data traffic appropriately. Data offloading techniques like LIPA/SIPTO reduces traffic loads on cellular core networks by introducing L-GWs (local gateways), whereas offloading techniques like WiFi offload/IFOM reduces traffic loads on cellular access networks by utilizing WiFi as a new radio access network (RAN) to existing cellular core networks. As access network is the main source of bottlenecks to cellular networks, IFOM/WiFi Offload technique shall be more effective a solution to alleviate the problem of cellular traffic loads thereby improving user experiences.

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APPENDIX A  ABOUT HUGHES SYSTIQUE CORPORATION

HUGHES Systique Corporation (HSC), part of the HUGHES group of companies, is a leading Consulting and Software company focused on Communications and Automotive Telematics. HSC is headquartered in Rockville, Maryland USA with its development centre in Gurgaon, India.

SERVICES OFFERED:

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System Integration : As system integrators of choice HSC works with global names to architect, integrate, deploy and manage their suite of OSS, BSS, VAS and IN in wireless (VoIP & IMS), wireline and hybrid networks.: NMS, Service Management & Provisioning.

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- Terminal Platforms : iPhone, Android, Symbian, Windows CE/Mobile, BREW, PalmOS
- Middleware Experience & Applications : J2ME , IMS Client & OMA PoC,

Access
- Wired Access : PON & DSL, IP-DSLAM,

Core Network
- IMS/3GPP , IPTV , SBC, Interworking , Switching solutions, VoIP

Applications
- Technologies : C, Java/J2ME, C++, Flash/lite,SIP, Presence, Location, AJAX/Mash
- Middleware: GlassFish, BEA, JBOSS, WebSphere, Tomcat, Apache etc.

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- Billing & OSS , Knowledge of COTS products , Mediation, CRM
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Platforms
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