Stand Alone or Non Stand Alone 5G Tactical Edge Network Architecture for Military and Use Case Scenarios

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***Abstract*—5G is a all-in-one communication network which provides high packet delivery at faster rate while serving a million simultaneous devices. Fifth generation (5G) network as being rolled out in India and abroad is not just a generational advancement but a complete digital network which provides multiple service pillars as mobile networks reach a stage where they are no longer being classified on the basis of speed rather on basis of milti-platform connectivity, slicing and visualization. 5G is being currently deployed as public and private network with number of deployment options as part of 5G Non Stand Alone (NSA) and 5G Stand Alone (SA). It is important that these deployment options are studied in detail before recommending a suitable option between NSA and SA so as to meet user requirements. Military communication is an outgrowth of civilian communication with use cases derived from the later as 5G brings the much needed speed, efficiency and precision to military communication and its decision support system. This paper brings out performance evaluation of 4G/ LTE, 5G NSA and 5G SA to examine if requirements of military use cases are met and recommend the most suitable network for deployment of Military 5G network based on simulations and Key Performance Indicators as available from campus network study.**

I. INTRODUCTION

The world currently is seeing the saturation of 4G network in deployments as 5G networks are being deployed to connect as many as 75 billion IoT devices by 2025 [1] which legacy 4G is incapable of and thus transition to 5G is inescapable. Third Generation Partnership Project (3GPP) under the umbrella of International Telecommunication Union - Radio Communication (ITU-R) [2] as part of standard defining body started taking inputs from eminent telecommunication institutes of countries across the world, network providers, academia and manufactures of telecom gear to set requirements for International Mobile Telecommunication-2020 (IMT-2020) [3]. Commercially 5G networks are being deployed in a progressive manner with 4G/ 5G Radio Access Network (RAN) being latched on existing 4G core network and later upgrading to full 5G network [4]. 5G as a network is elastic and scalable which opens a plethora of use cases in multiple verticals, new definition of service pillars is based on numerous other aspects such as latency, connection density, network slices and authentication flexibility towards other non 3GPP networks [5]. 5G as a network encompasses three service pillars which are scalable and configurable as per user requirement, thus in easy words an elastic network which is capable to fulfill Key Performance Indicators (KPI) [6] as defined by 3GPP and still provides customization. Three service pillars of 5G are Enhanced Mobile Broadband (EMBB), Ultra Reliable Low Latency Communication (URLLC) and Massive Machine Type Communication (MMTC), through these services 5G is capable of providing high speeds of 20 Gbps with lower time delay of 1 ms and latching 1 million devices respectively [7]. This is not just a generational shift but a complete new architecture which uses Software Defined Networking (SDN), Network Function Virtualization (NFV) and Network Slicing (NS) to make it a heterogeneous network providing multiple connectivity options for plethora of technologies like Bluetooth, WiFi, Internet of Things (IoT) devices and Low Power Wide Area Network (LPWAN) nodes [8].

TABLE I: Evolution of Mobile Communication

Network	Year	Technology	Max Data Rate
1G	1980	FDMA	2.4 KBPS
2G	1993	TDMA	14.4 KBPS
2G	2000	GPRS	115 KBPS
2G	2003	EDGE	384 KBPS
2G CDMA	2000	CDMA 2000 1X	153 KBPS
3G CDMA	2005	CDMA 2000 1X EVDO	2.4 MBPS
3G CDMA	2006	CDMA 2000 REV A	3.1 MBPS
3G CDMA	2008	CDMA 2000 REV B	14.4 MBPS
3G	2004	(UMTS)	480 KBPS
3G	2008	HSPA	3.6 MBPS
4G LTE	2010	LTE RELEASE 8	100 MBPS
5G NR	2020	IMT 2020 RELEASE 16	20 GBPS

With enormous connectivity options 5G can energize military communication networks for distributed command and control till the forward edge of battlefield [8] [9]. Precondition for a military network is security and privacy and in order to support such networks 3GPP 5G specifications provide a solution called non-public networks also called private networks [10] with customized specifications, specific spectrum and limited over a geographical area. 5G private networks can be designed as 5G Non Stand Alone (NSA) or 5G Stand Alone (SA), NSA network use a 4G Evolved Packet Core (EPC) to run 5G control plane and connect user handset through 4G spectrum and data plane running on 4G/ 5G radio thus providing dual connectivity. SA will connect the user handset through 5G spectrum using data plane on 5G New Radio (NR) base station and control plane on 5G Core Network (CN). Historically cellular generations provide 1x to 10x improvement in data rates over the older generation, however fourth generation (4G) also called Long Term Evolution (LTE) network extended this to design aspects also and was the first IP at Core network. It also extended connectivity to Internet of Things (IoT) though a mid life upgrade called as Narrow band IoT (Nb-IoT) [6] and LTE-Machine (LTE-M) [11]. Generations of mobile network are as following with maximum data rates given in Table 1:-

- First Generation 1G: Introduced in 1980 1G used analog modulation and worked on Frequency Division Multiple Access (FDMA) leading standards were Total Access Communication System (TACS) and Nordic Mobile Telephone (NMT).
- Second Generation 2G: Late 1980 saw the emergence of 2G network which was a digital secure network with anonymity, authentication and encryption algorithms. It provided max data rate of 14.4 Kbps and supported Multimedia Messaging Service (MMS). Global System of Mobile (GSM) and Code Division Multiple Access (CDMA) were the leading standards that evolved to General Packet Radio Switching (GPRS) as part of 2.5G and Enhanced Data Rate for GSM Evolution (EDGE) as part of 2.75G with max data rate of 384 Kbps.
- Third Generation 3G: International Mobile Telecommunication (IMT) 2000 was launched in 2000 while it got deployed in India by 2010, used Universal Mobile Telecommunication (UMTS) standard. Max data rate was 2 Mbps which was later enhanced to 3.6 Mbps as part of 3.5G using High Speed Packet Access (HSPA+).
- Fourth Generation 4G: Launched globally in 2010 based on Long Term Evolution (LTE) with a data rate of 100 Mbps and later enhanced to 1Gbps as part of LTE Advanced (LTE-A) is a IP at core network and provided all possible services. Available across multiple bands from 700 Mhz to 2900 Mhz, LTE also provided connectivity for IoT devices through a separate core called Narrow Band IoT (Nb-IoT) and LTE-M.

II. Motivation and Contribution

In this paper we compare 4G, 5G NSA and 5G SA network and highlight differences in technical parameters based on architecture and support towards use cases. This deliberation is required since 5G network is capital intensive and it is important to deploy a network which meets all requirements and also is future ready. The KPIs of 5G campus network as presented in [12] and [13] are evaluated vis a vis requirement of Military communication presented in [4] and [14]. Study of 3GPP Release-15/16 is also carried out along with effects of fading [15] affecting the coverage as part of RAN. Major contribution of this paper is to augment the understanding of various use cases as presented in Table V studied in conjunction with Table III and IV and further evaluation of same with KPIs as defined in [12] to explore the most suitable deployment architecture presented in Figure 3 and Figure 4. Simulation of 5G SA and NSA is also presented based on study carried out in [13].

III. System Model

5G KPI [12] data is presented in Table for calculation and simulation of link delay, packet loss, uplink/ downlink data rate and network latency. While communicating with UE on uplink mode the link is affected by fading and are separated by a distance d with the path gain model given as:

$$L \equiv L(d) = \left(\frac{\lambda}{4\pi d_0}\right)^2 \left(\frac{d_0}{d}\right)^v \tag{1}$$

The affect of fading is more at higher frequencies than at lower frequencies, where d_0 is the reference distance, λ is propagation wavelength and path loss exponent (PLE) is v. Link budget of base station is $R_{LB}(dBm) = T_x(gNb) + G_T + L + G_R - L_C - P_L - T_L - F_L - \eta_s - P_i - A_i$ where T_x represents transmit power G_T is gain of transmitter, G_R is gain of receiver, L is cable loss, $P - L$ is path loss, T_L is penetration loss, $F - L$ is foliage loss, η_s is slow scale fading and P_i is indoor attenuation. Open RAN simulator of key-sight technologies (Studio Builder) has been used with following parameters:-

TABLE II: Evolution of Mobile Communication

Configuration Parameter	**5G NSA**	**5G SA**
Carrier Frequency	700 Mhz	3.6 Ghz
Bandwidth	10 Mhz	50 Mhz
DL and UL Modulation	64 QAM	256 QAM
Distance of UE	3 m	3 m
Number of Antennas	2	4
BS transmit power	49 dBm	49 dBm
BS Height	100 cm	100 cm
5G UE	Nokia fast-mile	WNC SKM-5xE
Frequency Mode	TDD	TDD

TABLE III: Call Flow and Session Establishment in 4G, 5G NSA & 5G SA

Parameter	**4G**	**5G NSA**	**5G SA**
Data Network	PDN	PDN/ DN	DN
User Database	HSS	HSS/ AUSF	AUSF/ UDM
Policy Control	PCRF	PCRF/ PCF	PCF
External Interface	Nil	Nil	N3IWF
Session Management	MME	MME	SMF
RAN to CP	S1-MME	MME/ NGAP	N2 to AMF
Multiple Session	No	With 5GC only	Possible

TABLE IV: Comparison of KPIs of LTE, 5G NSA and 5G SA along with network attributes

Ser No	Use Case with 5G Service	4G/LTE	5G NSA	5G SA
(a)	**Network Centric Operation** Ability to picture oneself in relation to enemy • eMBB • mMTC	Limited and Delayed	Available	Available
(b)	**Unmanned Ground Vehicle** • uRLLC	Not Supported	Not Supported	Supported
(c)	**Remote Surgery** • uRLLC	Not Supported	Not Supported	Supported
(d)	**Simulation based Training** Use of AR / VR / MR to simulate battlefield experiance • eMBB • uRLLC	Not Supported	Limited Support	Supported
(e)	**Logistics Support and Health Monitoring** Use of IoT / IoMT / IoBT devices to track personnel and equipment • mMTC	Not Supported	Supported	Supported
(f)	**Command and Control Vectors** High bandwidth and high density deployment of • eMBB	Limited	Supported	Supported
(g)	**Side-link Communication** Ability to communicate without Infrastructure on AdHoc network • eMBB • uRLLC	Not Supported	Limited	Supported
(h)	**Technology Up-gradation for New Mission Capability**	Saturated	Capital Intensive	5G Advanced Ready

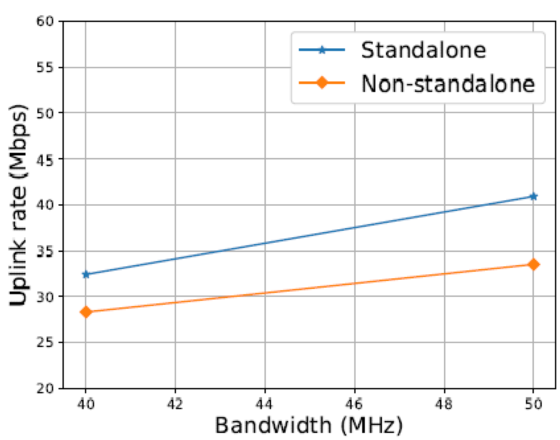

Fig. 1: Uplink rate of SA and NSA

IV. 5G Deployment Architecture

5G network is scalable, configurable, flexible and available in multiple options as per user requirement, through deployment architecture 5G can be optimized to meet user goals such as required latency of network, massive connectivity, cooperative communication and other desired scenarios. In general, 5G has two deployment architectures i.e. 5G SA and 5G NSA where SA describes a complete RAN of 5G NR where NSA uses existing LTE RAN. There are a total of seven deployment options as per 3GPP [16], out of which options 1, 2, 5 are SA based and options 3, 4, 7 are NSA based, option 6 is a non 3GPP standardized cases and option 1 is 4G/ LTE case and must not be confused with 5G SA. Call flow and session establishment details in respect of 5G CN are given in Table III. Details of SA and NSA options are as following:-

- **Option 1**: It describes a pure 4G RAN of eNb working on a EPC as a standalone system and since it doesn't have any NR elements thus not legacy LTE deployment.

- **Option 2**: A complete NR dominated option with 5G RAN of gNb working on a 5G CN without any legacy 4G/ LTE radio or core subsystems. This option is recommended for greenfield deployments where complete spectrum in low, mid and high band is available as it completely exploits the three service pillars of 5G i.e. eMBB, uRLLC and mMTC. It also supports 5G Core features such as Network Slicing (SA) and Inter-working with non 3GPP technologies through Non 3GPP Inter-working Function (N3IWF). Limitations of this options are high cost of deployment and low coverage since it doesnt have a dual connectivity.

- **Option 3, 3a, 3x**: Option 3 describes a family of NSA combinations where an next generation eNb (ng-eNb) is deployed with a 4G EPC and has two additional sub-options of 3a and 3x. In option 3, 4G eNb splits the data of two paths i.e. towards UE and ng-eNb, in option 3a, 4G EPC splits the data between eNb and ng-eNb and in option 3x is a mix of option 3 and 3a and is beneficial in cases where LTE has better coverage than NR. This option is easiest to deploy, however it does not support uRLLC service.

- **Option 4, 4a**: A complete NSA option where EPC is replaced with 5G CN and provides dual connectivity by means of NR gNb as the primary network and ng-eNb as the secondary network. This is a NR heavy network which also uses carrier aggregation between 5G and LTE bands. In option 4, gNb controls ng-eNb while in option 4a, 5G CN controls both gnb and ng-eNb.
- **Option 5**: An augmented SA option where eNb is upgraded to ng-eNb and is connected to a upgraded EPC. This option does not have support of dual connectivity and NR air interface i.e. sub carrier spacing and mmWave, however it supports network slicing.
- **Option 6**: A 3GPP non-standardized option which is untenable as it considers connection of a 5G gNb to 4G EPC and lets it control EPC.
- **Option 7, 7a, 7x**: Again a family of options in NSA mode evolved from option 3 and option, where both ng-eNb and gNb are interconnected and also connected to 5G CN providing dual connectivity and carrier aggregation among LTE and NR bands. Sub-option 7a uses the NR and LTE air interface to split data through ng-eNb and gNb while option 7x is a combination of 7 and 7a.

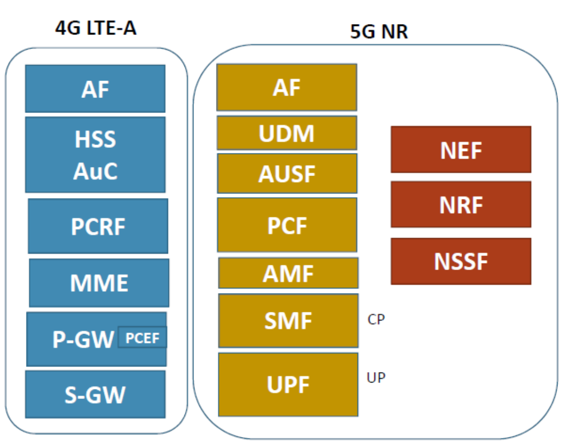

Fig. 2: CN function of LTE EPC and 5G CN

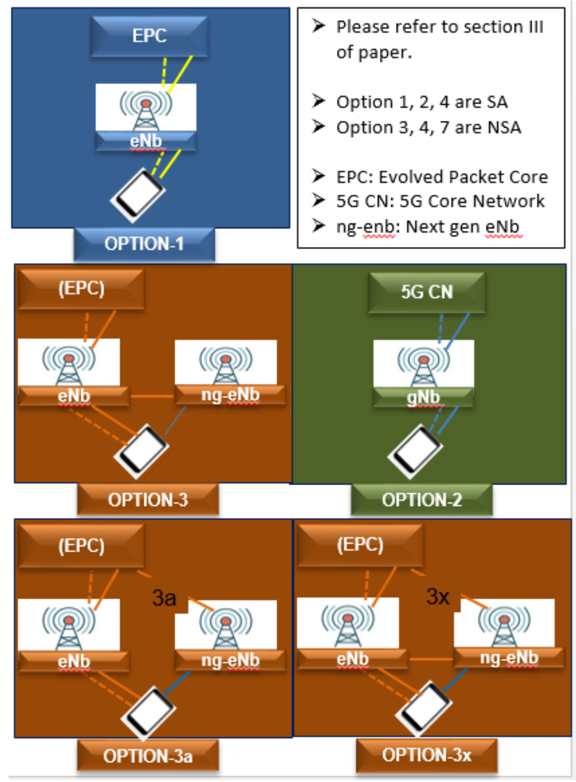

Fig. 3: Option 1 to 3x

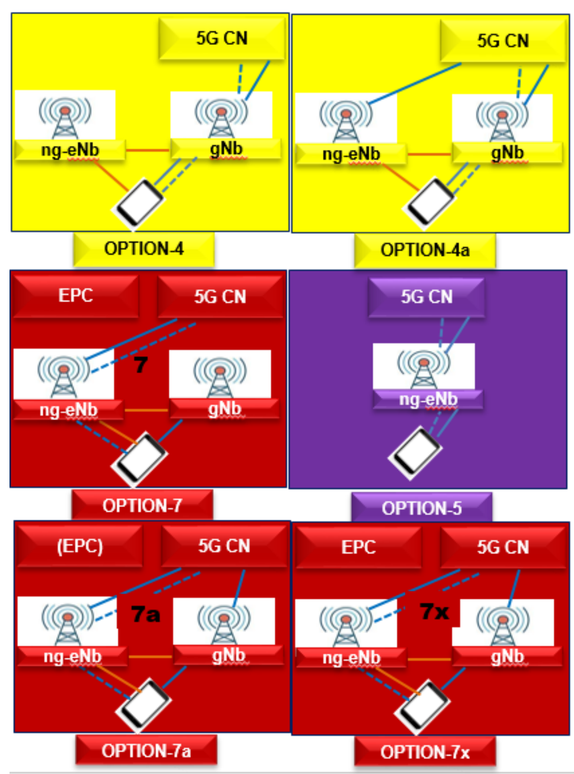

Fig. 4: Option 4 to 7x

TABLE V: Comparison of KPIs of LTE, 5G NSA and 5G SA along with network attributes

Ser No	Attributes		4G/LTE	5G NSA	5G SA
(a)	Service Objective		Connectivity to People	People and Things	People and Things
(b)	Coverage		High	High with LTE anchor	Medium
(c)	Voice Service		VoLTE	VoLTE	VoNR with EPS fallback
(d)	Handover		Seamless	Seamless due to Dual Connectivity	Delayed as Handover from 5GC to EPC
(e)	Power Consuption		Medium	Slightly higher than LTE	Low
(f)	QoS		Based on SDF without eNb	RRB without eNb	SDAF with gNb and RBs
(g)	User Device		Single link with eNb	Dual link with eNb and gNb	Single link with NR gNb
(h)	Network Complexity		Simple	Complex	Simple
(i)	Spectrum Utilization		Max 20 Mhz	100 Mhz contiguous	400 Mhz to 1 Ghz
(j)	Sub Carrier Spacing		15 Khz	15 Khz in case of 4G spectrum	15 / 30 /60/ 120/ 240 Khz
(k)	Future		Legacy Network	Under Transition	Target network towards 6G
(l)	KPI	Max data rate	100 Mb/s	1 Gb/s	20 Gb/s
(m)		User available data rate	10 Mb/s	100Mb/s	1 Gb/s
(n)		Spectral Efficiency	1X	2 X that of 4G	3 X that of 4G
(o)		Connection Density	10ˆ5 devices/ sq Km	10ˆ6 devices/ sq Km	10ˆ7 devices/ sq Km
(p)		Mobility	350 Kmph	350 Kmph	500 Kmph
(q)	Service Pillars		• Voice • Video • Limited IoT	• eMBB • IoT	• eMBB • uRLLC • mMTC
(r)	Technologies		• LTE-M • Turbo Code • Carrier Aggregation • Nb-IoT	• Dual Connectivity • Carrier Aggregation • LDPC and Polar Codes	• mmWave • NOMA • 256 x 256 MIMO • SDN / NFV / Network Slicing
(s)	Network Characteristics		Flat and All-IP	- Cloudization - Softwarization - Virtualization	- Intelligentization - Virtualization - Slicing
(t)	Applications		• Voice • Mobile TV • Low resolution videos	• HD Videos • IoT • Smart City • Wearables	• V2X • Tactile Internet • Telemedicine • AR / MR / VR • Automated Driving

V. NECESSASITY OF 5G FOR MILITARY AND USE CASES

5G energies mission type command system which creates multiple battlefield variables to be analyzed through mission oriented chain of command at command centers. 5G enables cross platform connections and distribution of information in terms of location, health status of combatants, surveillance inputs and unmanned systems to commanders with organic integration of AI. Services of 5G provide an opportunity for exploitation to meet operational requirements of military communication by enabling integrated multimedia services and massive connectivity.

A. *Smart Soldier*

5G with its futuristic network can carry out soldier automation and improve his ability in terms of communication with peers, geolocate himself and track enemy movement with help of surveillance resources. This new mission capability lets a soldier access helmet mounted cameras of other soldiers, mark enemies on map, view health status of his team, update and share new mission objectives and thus improve the overall situational awareness.

B. *Autonomous Mini Patrol Drones*

5G provides necessary bandwidth for UHD/ HD streaming of drone camera feed and its fusion with Artificial Intelligence (AI), Computer Vision (CV) engine hosted at a central location can augment mini/ micro drones to act as patrol drones. Video stream forwarded by these drones can be channelized through a AI engine for detection of particular suspects based on current situation i.e. AI engine to detect humans in combat uniform/ small arms. These drones can be deployed in package as surveillance, tracking or targeting drones to automate the kill cycle.

C. *Field Wireless Access*

mmWave has ability to provide very high bandwidth and data rate to users and devices in a small cell environment thus mitigating threat of interception by enemy Electronic Support Measures (ESM) activity. 5G small cell is meant for field headquarters which are either mobile or mechanized and spread in a small area with high density of devices to support commanders with real-time battle field data and provide agile command and control vectors.

D. Augment Intelligence, Surveillance, Reconnaissance (ISR) Grid

Defensive application of 5G is its deployment to support a ISR grid along borders to convert contemporary fence into a smart fence by means of Internet of Military Things (IoMT) devices which are ultra low powered sensors such as seismic, pressure, temperature, piezoelectric and ultrasonic. Deployment of such sensors enhance electronic surveillance and helps in reduction of troops, also additional algorithms can be employed to automate actions upon detection of any movement such as automated recces missions by patrol drones.

VI. Discussion

In this paper we have enumerated a complete technical comparison of 4G, NSA and SA architecture for evaluating suitability for particular use cases. Table II and Table III define simulation parameters and call processing in case of 5G NSA and SA. Table IV tabulates use cases vis a vis 5G service and support of same from LTE and options of 5G. It can be seen from Figure 1 that 5G SA has better uplink performance to 5G NSA, also the latency is higher in case of NSA since the same does not use an E2E architecture. Table IV also shows that that most of the use case requirements of military are met by NSA, however those which require low latency are only supported by SA network. Table V compares KPIs of 4G, NSA and SA networks and it can be seen SA provides better performance than NSA or 4G. The network complexity and UE complexity is reduced in case of 5G SA network, though it provides lesser coverage.

VII. Conclusion

Armed forces must speed up deployment of 5G to boost capabilities while also ensuring that a elastic, resilient and suitable option be implemented which meets requirement of military use cases. 5G SA is the recommended option for greenfield deployments and for optimum exploitation of 5G network as all envisaged use cases can be supported by it. Future focus is to use KPIs and parameters presented in table II to simulate other network functions such as orchestration of network slicing and QoS.

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