128 TECHNOLOGY

5G Mobile Networks

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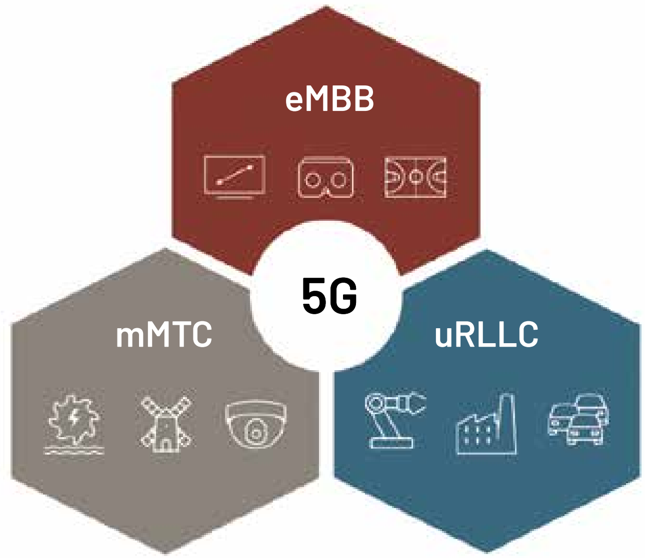
Introduction

Fifth generation wireless technology, known as 5G, is expected to enable Internet of Things (IoT), self-driving cars, augmented reality (AR) and industrial automation. Mobile services continue to demand higher bit rates, lower latency, greater reliability, and robust coverage. Standardization[1,2] and early trials of 5G are already underway. The International Telecommunication Union (ITU) has classified 5G mobile network applications into three categories[3]:

- Enhanced mobile broadband (eMBB): This includes ultra-broadband applications such as 4K video, AR, and virtual reality (VR). These applications generate high traffic volumes for amazing multimedia experiences.
- Massive machine-type communications (mMTC): This includes connected devices such as sensors, meters, and home security. These applications have high density such as smart cities and smart agriculture.
- Ultra-reliable and low-latency communications (uRLLC): This includes vehicle-to-vehicle communications, industrial automation, and robotics. These applications require high reliability and low-latency such as for assisted and automated driving.



Mobile networks traditionally had radio functions at cell towers and mobile processing functions at a data center in the core. To support capacity, latency, density, and reliability associated with eMBB, mMTC, and uRLLC, network architectures and technologies for 5G networks are going to be transformed. Network functions and computation nodes will be distributed and moved closer to the network edge to address low latency requirements while some functions can be centralized. Mobile traffic will need to be dynamically routed to various processing points. Traditional VPN and MPLS technologies used to backhaul network traffic to centralized points will not be sufficient to meet these demands.

The 128 Technology Smart Session™ router provides end-to-end IP routing, fast convergence, dynamic routing with run-time decision making, segmentation for network slicing, and simplicity required for the 5G era.

Technical Requirements

Traditional mobile communication networks employ a one-size-fits-all approach. There is no differentiation in terms of how different mobile services are handled by the network. The requirements that applications place on the network for self-driving cars, remote surgery, immersive experiences, and smart cities is very different.

Software defined networking (SDN), network function virtualization (NFV), and mobile edge computing (MEC) are touted as possible solutions. The network needs to evolve to provide differentiated services per application or service type.

[1] 3GPP, "System Architecture for the 5G System", TS.23.501

[2] 3GPP, "Procedures for the 5G System", TS.23.502

[3] ITU, "IMT Vision—Framework and Overall Objectives of the Future Development of IMT for 2020 and Beyond", ITU-R M.2083-0.

The requirements for 5G networks are as follows:

Throughput

AR and VR can provide immersive experiences. However, using AR or VR for a long time can cause dizziness and motion sickness. There many requirements to improve this experience including improving image quality, viewing angle, increasing refresh rate, and decreasing motion-to-photon latency (time required to reflect user motion on a display screen). 5G networks require supporting high bandwidth with low latency for these applications.

For massive and instant content sharing, 4K/8K video, immersive experiences, and 3D holograms along with the large number of users and smart devices per cell, 5G networks must support 20 Gbps downlink peak data rate and 10 Gbps uplink peak data rate. This requires a 1000x improvement in network capacity compared to current networks.

Scale

The minimum requirement for connection density[4] for 5G network is 1M devices per km^2.

Wearable devices including smart watches, smart glasses, health monitors, and motion monitors are required for smart personal network services. Smart buildings will contain sensors, temperature controllers, security cameras, smart locks, and various energy efficient controllers. Farms of the future will have sensors to monitor temperature, humidity, wind speeds, and sunshine. Soil quality sensors, smart irrigation systems, livestock implants and sensors along with other intelligent systems will enable farmers to reduce costs and improve efficiency. Logistics of the future will include smart sensors.

To accommodate this explosion of devices with mMTC, there is a need for the network to be able to uniquely identify endpoints and provide each one of them with differentiated services. Current networks cannot scale to maintain these connections.

Reliability

5G networks require 99.999% service availability even in extreme situations. It is expected to guarantee single packet transmission failure per 10K or 100K transmissions. This is a must-have to meet the demands of disaster monitoring, public safety, emergency services, drones, robots, remote surgeries, etc. Today's networks are designed to provide best effort or best possible service. However, the 5G infrastructure is expected to support mission critical services requiring very high reliability.

Latency

Intelligent traffic management, automated and assisted driving cars, and smart transportation require improved safety, higher reliability, and superior efficiency from the network.

The minimum requirement for user plane latency for URLLC is 1 ms over the radio interface. A car must receive a braking control command within 1 ms to guarantee safety. The latency of a 4G network is 50ms. A car travelling at 100km/h will travel 1.39 m from the time it discovers an obstacle to the time it starts braking in a 4G network. This latency is unacceptable to avoid a collision. With a 5G network with 1 ms latency, the car will travel 2.8 cm which is comparable with an anti-lock braking system (ABS). To achieve this latency, compute resources must be placed close to network edges and base stations. This requires the network to enable high speed communications and direct traffic to the closest compute nodes for uRLLC services.

Mobility

Four classes of mobility are defined for 5G:

- Stationary: 0 km/h
- Pedestrian: 0 km/h to 10 km/h
- Vehicular: 10 km/h to 120 km/h
- High speed vehicular: 120 km/h to 500 km/h

Self-driving cars, mobile broadband services in cars, trains, and airplanes, sensors and location tracking for cars, trains, and airplanes, and other services require high mobility and session survivability. Today's networks are not designed to support seamless connectivity to terminals moving at speeds of 500 km/h. Service pinning or distributed mapping of endpoints cannot support high speed mobility.

Cost

5G networks require to reduce costs even when handling huge volumes of traffic. Operators continue to leverage white boxes[5], software, and virtualization to drive down CAPEX and OPEX. It is a must-have for operators to move away from hardware centric networks to white boxes. 5G networks must be simpler and easier to manage compared to traditional networks deployed today.

[4] ITU, "Minimum requirements related to technical performance for IMT-2020 radio interface(s)", ITU-R M.[IMT-2020.TECH PERF REQ]

[5] AT&T, "AT&T is Deploying White Box Hardware in Cell Towers to Power Mobile 5G Era" March 25, 20

128T for 5G

The technical requirements for 5G can be translated to network requirements supported by the 128T Session SmartTM router as follows:

Technical Requirements	**Network Requirements**
Throughput *Tens of Gbps peak data rate*	Software based Solution *Programmable hardware that can scale dynamically*
Scale *1M devices per km2*	Service oriented Routing *Tunnel free routing to scale to millions of sessions*
Reliability *99.999% service availability*	Failsafe Delivery *Ability to maintain sessions in case of failures*
Latency *1ms over radio interface*	Service oriented Routing *Direct sessions to closest locations for low latency* transmission
Mobility *Seamless connectivity at 500 km/h*	Service oriented Routing *Ability to maintain session context during mobility*
BCost *White box and simple solution*	Routing with Words/ZTP/Software based Solution *Easy to add/remove/modify services globally*

The 128T Session SmartTM router inherently supports the features required to enable 5G services.

Service Oriented Routing

Service oriented Routing is an innovative service-centric, session-oriented, and security-infused routing paradigm for building context aware networks. 128T Session Smart™ routers, deployed at network edges, transform a state-less L2 fabric or L3 network data plane into a fully session aware data plane through sessionbased signaling and waypoint routing.

User equipment[6] (UE) can be assigned IP addresses that may or may not change. The 128T Session Smart™ routers are placed alongside the gNB/eNodeB[7]. The 128T routers are also placed alongside the UPF/pGW[8]. The 128T routers use waypoint routing to communicate with each other. This separates the UE address and enables mobility. When a UE moves off a gNB/eNodeB and sends packets from another gNB/eNodeB, the receiving 128T router is able to detect that the session is a continuation. This ensures session persistence and high-speed mobility. There is no need for any complex signaling protocol, hair-pinning, or mapping system update required to guarantee mobility

[6] User Equipment as defined by [GPRS-3GPP] is typically a mobile phone. The UE is connected to the network across the RAN to gNB/eNodeB nodes.

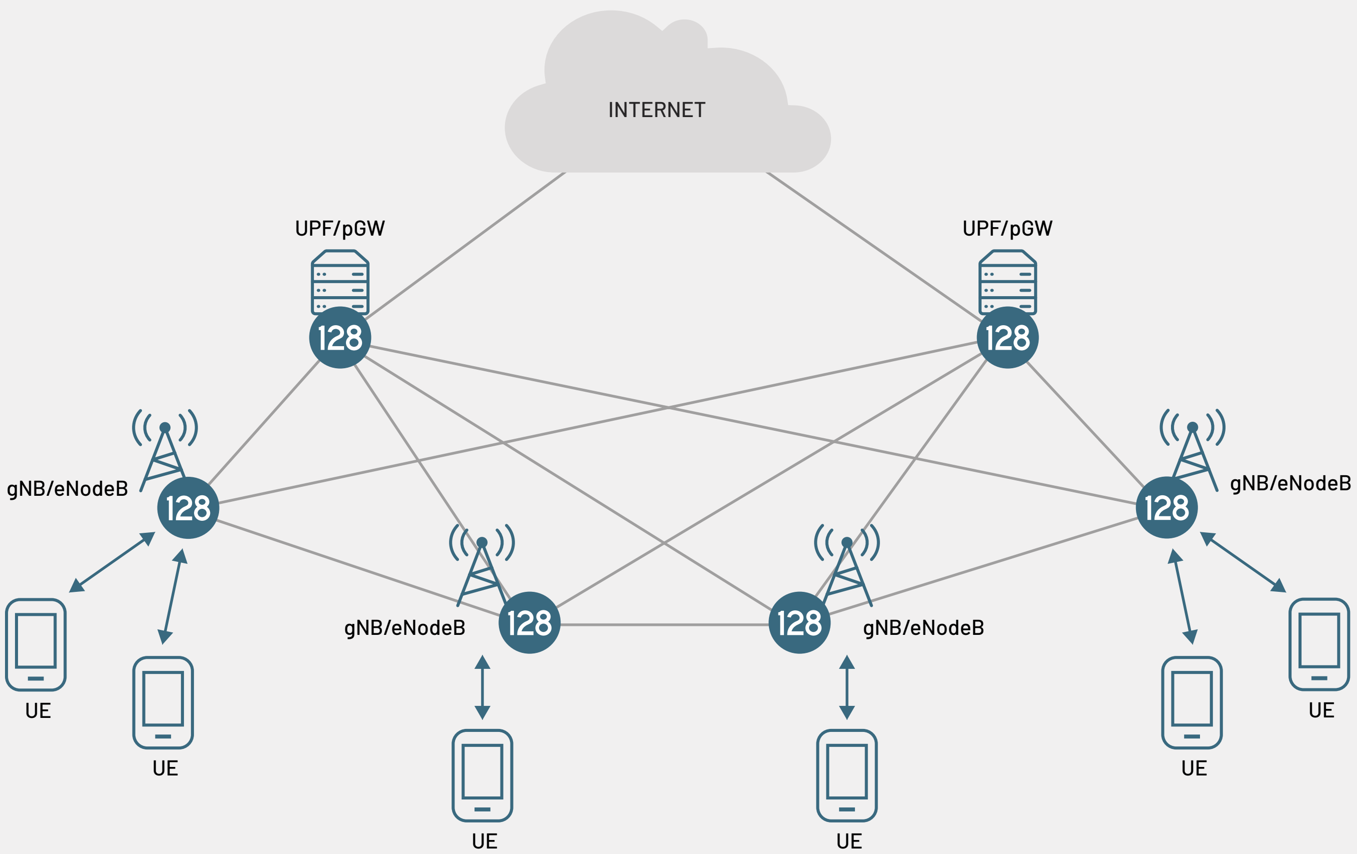
[7] gNB/eNodeB is the device defined by [GPRS-3GPP] which borders the RAN and connects UEs to the EPC.

[8] UPF/pGW is the PDN-Gateway as defined by [GPRS-3GPP] connects the EPC to the Internet.

The 128T routers do not use encapsulations or tunnels for communication they can support millions of sessions which supports the large scale of devices that a 5G network is expected to support per gNB/eNodeB. All 128T routers directly communicate with each other ensuring that the most optimal path is selected which prevents any added latency.

The 128T routers allow for each session to be routed, encrypted, and authenticated individually. This ensures hyper-segmentation and network slicing giving each session differentiated services. Policy on the 128T routers ensure that each session is directed towards the desired destination. In combination with MEC, compute resources can be located closer to the UEs for uRLLC services.

Global policy and security definitions allow for instantaneous changes in policy definitions. This provides a simple mechanism to add/remove/modify services. Routing with words hides the complexity of dealing with thousands of IP addresses. Zero-touch provisioning (ZTP) enables new 128T routers to be deployed dynamicallyon any commodity platform.



Fail Safe Delivery

The 128T routers can be deployed as a High-Available (HA) pair. This ensures that failure on any single router does not affect the sessions. The 128T routers operate in active-active mode with both routers processing traffic and sharing network load. Stateful failover ensures that the sessions are maintained in case of any failure. This ensures session survivability for automated cars and emergency services.

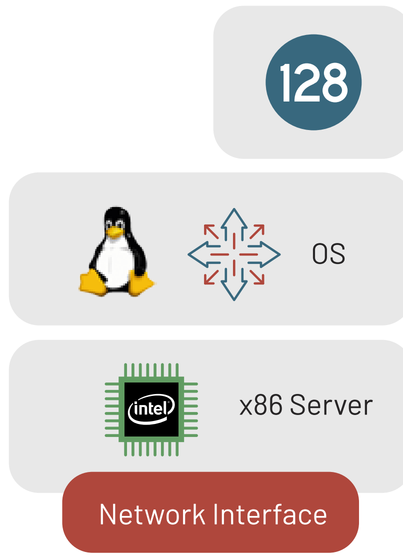
The 128T routers actively monitor paths among themselves and can find alternate paths between themselves when the link between them is affected. Session migration provides the ability to migrate an existing session to an alternate path. Multi-path session migration requires that packets can be forwarded not only on the shortest-path tree but on another maximally redundant path. This guarantees 100% recovery for single failures when the paths are completely disjoint.

Session Redundancy provides the ability to send the same session over two paths in the network. This ensures zero packet loss when any one path is affected. The receiving 128T router removes duplicates. Quality of Service (QoS) on the 128T routers ensure that high value sessions are provided higher priority in case of congestion.

Software Based Solution

The 128T routers provide line-rate forwarding on any commodity hardware. White boxes enable a provider to have the best possible prices.

The 128T routers are designed to scale linearly with the hardware resources available. This provides the ability to scale up the 128T routers depending on the amount of traffic. eMBB and mMTC services that require large throughput can be supported.



Summary

128T Session Smart™ routers brings context awareness to the network by associating transient sessions. It enables centralized management, granular control, individualized flows, infused security, and dynamic traffic management. These inherent benefits enable the network to become context aware and enable it to deliver unsurpassed quality, reliability, and scale to applications. The ability to separate UE identifiers from routing and the ability to maintain sessions during UE mobility provides session survivability which is a must-have for high speed mobility required for 5G. The 128T router can support the requirements for eMBB, mMTC, and uRLLC which are required for 5G.

5G will require a transformation in the network to support new services. The 128T Session Smart™ router is the best choice for 5G.

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