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WORK INTEGRATED LEARNING PROGRAMMES

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MANET Authentication Architecture

- Digital signatures to authenticate a message
- Key distribution via certificates
- Need access to a certification authority
- Specifies message formats to be used to carry signature, etc.

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Intrusion Detection

- Detection of abnormal routing table updates
  - Uses "training" data to determine characteristics of normal routing table updates (such as rate of change of routing info)
  - Efficacy of this approach is not evaluated, and is debatable
- Similar abnormal behavior may be detected at other protocol layers
  - For instance, at the MAC layer, *normal* behavior may be characterized for access patterns by various hosts
  - Abnormal behavior may indicate intrusion

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Mobile Networks

(SSWT ZG578)

Wireless Sensor Networks (WSN)
&
Vehicular Ad hoc Networks (VANET)

Contact Session-11

IMP Note to Self

IMP Note to Students

- It is important to know that just login to the session does not guarantee the attendance.
- Once you join the session, continue till the end to consider you as present in the class.
- IMPORTANTLY, you need to make the class more interactive by responding to Professors queries in the session.
- **Whenever Professor calls your number / name ,you need to respond, otherwise it will be considered as ABSENT**

Wireless Sensor Network (WSN)

Wireless sensors that collect everything from temperature and pressure readings to noise and humidity levels, can form an ad hoc network to deliver information to a home base without needing to connect directly to it.

A sensor node – Requirements:

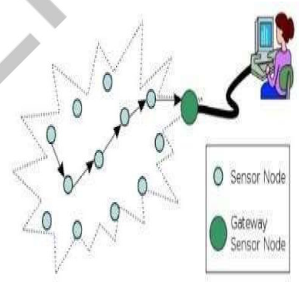
- 8K RAM, 4Mhz processor
- magnetism, heat, sound, vibration, infrared
- wireless (radio broadcast) communication up to 100 feet

Why use a WSN?

- Ease of deployment
  - Wireless communication means no need for a communication infrastructure setup
  - Drop and play
- Low-cost of deployment
  - Nodes are built using off-the-shelf cheap components
- Fine grain monitoring
  - Feasible to deploy nodes densely for fine grain monitoring

Wireless Sensor Network (WSN)

- The Wireless Sensor Networks (WSN) are special category of Adhoc wireless network that are used to provide a wireless communication infrastructure among the sensors deployed in a specific application domain.
- Sensor nodes are tiny devices that have capability of sensing physical parameters processing the data gathered, & communication to the monitoring system.



Issues of adhoc wireless network

- Density of deployment
  - The density of nodes in a sensor network varies with the domain of application.
  - For example, Military applications require high availability of the network, making redundancy a high priority.

Issues of adhoc wireless network

- Power constraints
  - The power constraints in sensor networks are much more stringent than those in ad hoc wireless networks.
  - This is mainly because the sensor nodes are expected to operate in harsh environmental or geographical conditions, with minimum or no human supervision and maintenance.

In certain case, the recharging of the energy source is impossible.

  - Running such a network, with nodes powered by a battery source with limited energy, demands very efficient protocol at network, data link, and physical layer
  - Data / Information fusion
- Data fusion refers to the aggregation of multiple packets into one before relaying it.

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The power sources used in sensor networks

- Replenishable Power source:
  - The power source can be replaced when the existing source is fully drained.
- Non-replenishable Power source:
  - The power source cannot be replenished once the network has been deployed. The replacement of sensor node is the only solution.
- Regenerative Power source:
  - Here, Power source employed in sensor network have the capability of regenerating power from the physical parameter under measurement.

Data / Information fusion in Wireless Sensor Networks

- Data fusion refers to the aggregation of multiple packets into one before relaying it.
- Data fusion mainly aims at reducing the bandwidth consumed by redundant headers of the packets and reducing the media access delay involved in transmitting multiple packets.
- Information fusion aims at processing the sensed data at the intermediate nodes and relaying the outcome to the monitor node.

Wireless Sensor Networks

- Traffic Distribution
- The communication traffic pattern varies with the domain of application in sensor networks.
  - For example, the environmental sensing application generates short periodic packets indicating the status of the environmental parameter under observation to a central monitoring station.
- This kind of traffic requires low bandwidth.
  - Ad hoc wireless networks generally carry user traffic such as digitized & packetized voice stream or data traffic, which demands higher bandwidth.

Challenges in sensor networks

• Energy constraint	: Nodes are battery powered
• Unreliable communication	: Radio broadcast, limited bandwidth, bursty traffic
• Unreliable sensors	: False positives
• Ad hoc deployment	: Pre-configuration inapplicable
• Large scale networks	: Algorithms should scale well
• Limited computation power	: Centralized algorithms inapplicable
• Distributed execution	: Difficult to debug & get it right

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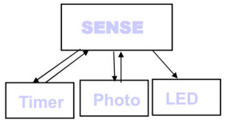
Event-Driven Sensor Access Pattern

```
command result_t StdControl.start() {
    return call Timer.start(TIMER_REPEAT, 200);
  }
event result_t Timer.fired() {
    return call sensor.getData();
  }
event result_t sensor.dataReady(uint16_t data) {
    display(data)
    return SUCCESS;
  }
```



- clock event handler initiates data collection
- sensor signals data ready event
- data event handler calls output command
- device sleeps or handles other activity while waiting
- conservative send/ack at component boundary

Programming Syntax

- TinyOS 2.0 is written in an extension of C, called nesC
- Applications are too
  - just additional components composed with OS components
- Provides syntax for TinyOS concurrency and storage model
  - commands, events, tasks
  - local frame variable
- Compositional support
  - separation of definition and linkage
  - robustness through narrow interfaces and reuse
  - Interpositioning
- Whole system analysis and optimization

WSN services

- MAC protocols (BMAC, SMAC, TMAC, etc.)
- Topology control (GAF, SPAN, CEC, etc.)
- Clustering (Leach, FLOC, etc.)
- Time synchronization (Flooding time sync, reference broadcast)
- Localization (cricket, range-free techniques...)
- Routing (convergecast tree, geographic routing, hierarchical...)
- Querying (DSIB, DQT, directed diffusion, etc.)
- Tracking (Stalk, Trail, etc.)
- Network reprogramming

Vehicular Ad hoc network

(VANET)

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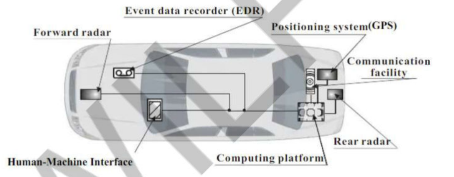
Vehicular ad hoc network (VANET)

- VANET consists of groups of moving or stationary vehicles connected by a wireless network.
- Until recently, the main use of VANETs was to provide safety and comfort to drivers in vehicular environments.
- Example applications of VANETs are: Electronic brake lights, which allow a driver (or an autonomous car or truck) to react to vehicles braking even though they might be obscured (e.g., by other vehicles).

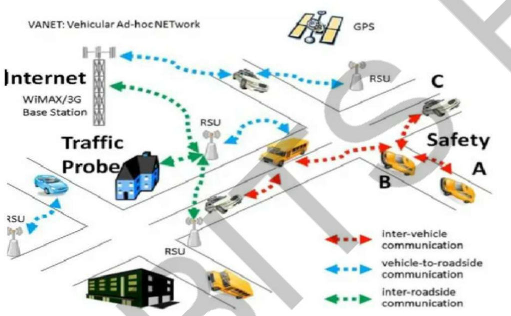
A modern vehicle

A modern vehicle is a network of sensors/actuators on wheels

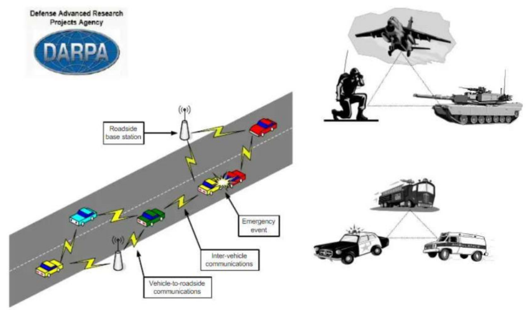


A Smart vehicle's onboard instrumentation. The computing platform supervises protocol execution, including those related to security. The communication facility supports wireless data exchange with other vehicles or fixed stations (Source: Hubaux, Capkun and Luo, 2004).

What is a VANET?



What is a VANET (Vehicular *Ad hoc* NETwork)?



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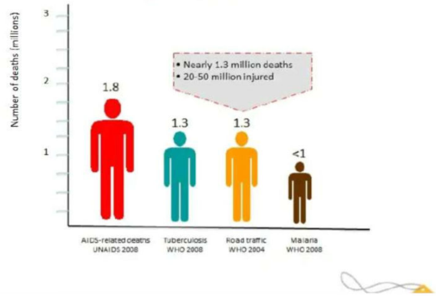
Key facts



Vehicular Communications : WHY?

- Combat the awful side-effects of road traffic
  - In the EU, around 35000 people die yearly on the roads; more than 1.6 millions are injured*
  - Traffic jams generate a tremendous waste of time and of fuel
- Most of these problems can be solved by providing appropriate ***information*** to the driver or to the vehicle

*Annual Statistical report 2010 published by the European Road Safety Observatory

Road traffic injuries will rise to the 5th cause of death by 2030

Leading causes of death, 2004 and 2030 compared

TOTAL 2004

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic obstructive pulmonary disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancers	2.3
9	Road traffic injuries	2.2
10	Prematurity and low birth weight	2.0
11	Neonatal infections and other	1.9
12	Diabetes mellitus	1.9
13	Malaria	1.7
14	Hypertensive heart disease	1.7
15	Birth asphyxia and birth trauma	1.5
16	Self-inflicted injuries	1.4
17	Stomach cancer	1.4
18	Cirrhosis of the liver	1.3
19	Nephritis and nephrosis	1.3
20	Colon and rectum cancers	1.1

TOTAL 2030

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Chronic obstructive pulmonary disease	7.0
4	Lower respiratory infections	5.1
5	Road traffic injuries	3.6
6	Trachea, bronchus, lung cancers	3.5
7	Diabetes mellitus	2.5
8	Hypertensive heart disease	2.3
9	Stomach cancer	2.2
10	HIV/AIDS	2.0
11	Nephritis and nephrosis	1.9
12	Self-inflicted injuries	1.9
13	Liver cancer	1.7
14	Colon and rectum cancer	1.7
15	Oesophagus cancer	1.5
16	Violence	1.4
17	Alzheimer and other dementias	1.4
18	Cirrhosis of the liver	1.3
19	Breast cancer	1.3
20	Tuberculosis	1.1

Source: World health statistics 2008 (http://www.who.int/whosis/whostat/2008/en/index.html)

World Health Organization

VANET applications

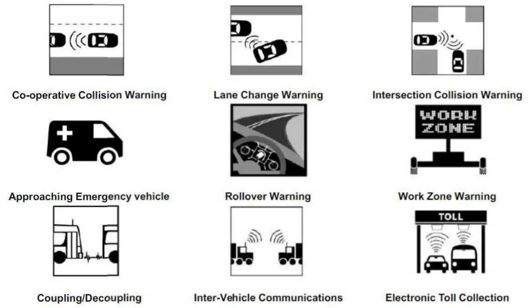
Safety-related applications

- Assistance
  - Navigation
  - Cooperative collision avoidance
  - Lane-changing
- Information
  - Speed limit
  - Work zone info
- Warning
  - Post-crash
  - Obstacle
  - Road condition warnings

Non Safety-related applications (Comfort-related)

- Weather information
- Instant messaging
- Online games
- Internet access
- Advertisement

VANET Applications



Standards and Regulations

- Communication: typically over a dedicated channel:
  Dedicated Short Range Communications (DSRC)
  - In the US, 75 MHz at 5.9 GHz;
  - In Europe, 30 MHz at 5.9 GHz;
- Envisioned protocol: IEEE 802.11p

Major Concerns

- Location-related broadcasting/multicasting support
- QoS support: reliability and delay
- Scalability
- Cooperation
- Security

Network Layer Challenges

- Traditional ad hoc routing VS. store-and-forward (stateless) routing
- Location-based unicast routing: location is known.
- Geocast routing: Location-related broadcast and multicast routing
- QoS support: reliability and delay
- Mobility prediction: Movements are restricted and mobility parameters are known.
- Routing in hybrid wireless networks (fixed roadside access points + mobile node)

IMP Note to Self

Mobile Networks
(SSWT ZG578)

Contact Session-11 :
Design Considerations in Wireless Sensor Networks- Energy Management Protocols

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Course Objective

Energy efficient Protocols in wireless Sensor Networks-Wireless Underwater Sensor Network (WUWSN)-Energy management Protocol

Sensor Network Applications

Environmental Monitoring
Animals/Plants Habitat Monitoring
Building/Bridges Structural Monitoring
Medical diagnostics
Natural disaster monitoring
Military Applications
Traffic monitoring.
Smart home appliances.
Inventory management etc….

Sensor Node Issues

Limited in computation
Low memory
Low power resources
Slow communication speed
Small bandwidth
May not have global identification
More prone to failures due to harsh deployment environments and energy constraints
Need to be densely deployed in most environments.

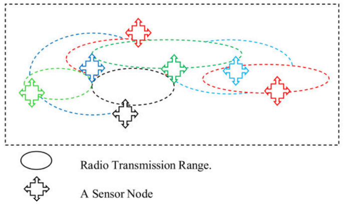

Figure. A Wireless Sensor Network

- As shown in the Figure, the network between the sensor devices is established through the radio component of the sensors.
- A wireless sensor network can consist of hundreds of sensor nodes.
- During the communication process, the sensor nodes exchange information and discover the neighbouring nodes easily.

Wireless Underwater Sensor Network (WUWSN)

WUWSNs are different from the ground-based wireless sensor networks in terms of the communication methods and the mobility of the nodes.

For communication, WUWSNs use acoustic signals instead of radio signals.

Acoustic signals are used due to their lower attenuation in underwater environment.

Energy Constraints

Energy is required in every mini or major operation of any type of application.

Sensors are equipped with batteries, but these batteries do have a limited life time,e.g. in underwater scenario, there are no plug-in sockets to provide the power as per the requirement.

The battery technology is still lagging behind the microprocessor technology. Energy-Efficient networking protocols are required now days.

Energy Conservation

Turn-off the transceiver when not required.

Use shorter data packets for the communication.

Multiple paths could be derived and used to reach the destination, to increase the network lifeline.

Data should be transmitted by the source node only when the destination node is ready, so that data could be reach without error at first place.

Avoid collisions between nodes.

Node idle-listening and overhearing should not happen in the network working.

Multi-hop data transfer can save a lots of power in the sensor network working.

Literature Survey

At the MAC layer, energy usage can be minimized by:

Avoiding collisions

Avoiding overhearing

Avoiding idle-listening

Avoiding control packets overrun

Avoiding again and again transitions between various modes viz. sleep, idle, transmit and receive.

Literature Survey…

At the network layer, energy usage can be minimized by:

Efficient routing: Routing is the process of finding the path from the source node to the destination node. An efficient established path could save a large amount of network energy and increase its productivity.

Reliable communication among sensor nodes: In a network when sensor nodes collect the data, the collected data needs to be sent to a master collector. The source node sends the data to the master collector acting as the destination node either directly or through relay. Reliable communication will save the energy that can be consume in data re-sending and data checking.

Literature Survey…

For terrestrial sensor networks, some of the existing energy efficient routing protocols are:

- Directed Diffusion
- Rumor Routing
- LEACH (Low-Energy Adaptive Clustering Hierarchy)
- TTDD (Two-Tier Data Dissemination)
- GEAR (Geographic and Energy Aware Routing)

Directed Diffusion

Data-centric protocol.

Diffusing data through sensor nodes by using the naming schemes for data.

By naming scheme, energy is saved as it avoids unnecessary operations of network layer.

Under naming scheme, it uses attribute-value pairs for the data.

By using these pairs sensors are queried on demand basis.

An interest is defined with the attribute-value pairs such as time duration, geographical location etc.

Interest entry also contains several gradient fields.

Gradient is a reply link with a neighbour from which the interest was received.

By interest and gradients, paths are established between source and data collector node.

Multiple paths have been established and out of them one is selected by the source node for the information passing.

Rumor

Another variation of Directed Diffusion protocol.

Applicable where geographic routing cannot be used.

Rumor creates the concept of flooding that is between the event flooding and the query flooding.

Main Idea is to route the queries to the node that has observed a particular event. This will save the entire network flooding.

When a node detects any event, it generates an agent.

Agent task is to communicate the information about the event.

When a node queried for an event, another node that knows about the route respond to the query by referring its event table.

This saves the cost of flooding the entire network.

Rumor protocol maintains only one path between source and destination, while in Directed diffusion multiple paths exist for data passing between source and destination.

Low Energy Adaptive Clustering Hierarchy

Cluster-based

Forms cluster to minimize the energy dissipation.

Operation of the protocol is divided into two parts: - Set-up phase and the Steady phase.

Steady phase is of longer duration to minimize the overheads.

Set-up Phase

- After selection of cluster-head, it advertises to all of its presence.
- After advertisement, the other sensor nodes decide whether they want to part of this cluster-head's cluster or not, based on the signal strength of the advertisement.
- Cluster-head assign the time-table to the sensor nodes of its cluster based on the TDMA approach. At the indicated time the nodes can send data to the cluster head.

Leach…

Steady-up Phase

- Sensor nodes start sensing and transmitting data to cluster-heads.
- Cluster-head aggregate all the data and send to the base station.
- After a certain period of time, network goes again to Set-up phase and again starts a new round of cluster-head selection.

E-Leach

Energy-LEACH protocol improvement over the LEACH protocol.

Changes the cluster-head selection procedure.

When first time (at first round), a cluster head is to be chosen, all the nodes have same probability to be cluster-head.

After first round, nodes' energy is also considered in cluster-head selection.

Node with high residual energy is chosen as cluster-head.

TL-Leach

Two-Level Leach. Sends data to the base station in two hop.

Cluster-head collects data from the other nodes.

Cluster-head send the collected data to the base station through another cluster-head that lies in between it and base station.

M-Leach

Multi-Hop Leach protocol. Data is relayed to the base station in multi hop.

This protocol addresses the problem of data transmission from the far clusters to the base station.

Cluster-head send the collected data to the base station through another cluster-heads that lie in between it and base station.

Due to multi-hop communication a lot of energy is saved at the cluster-head node.

Leach-C

Centralized Leach protocol. This introduces the centralized cluster formation algorithm.

During set-up phase, nodes send their remaining energy and location to the sink.

After that sink runs a centralized cluster formation algorithm and forms the clusters for that phase.

In each round, new clusters are formed by the sink.

This protocol distributes the cluster-heads throughout the network based on the nodes energy and location, hence may produce better results.

V-Leach

New Version Leach protocol.

In this new version protocol, a cluster will have the cluster-head as well as a vice-cluster-head too (CH and vice-CH).

Vice-cluster-head will take the authority of the cluster when the existing cluster-head dies.

This concept saves the energy of the cluster's members which they use in data collection. As if cluster-head dies, the collected information could not reach to the sink and result in energy wastage of the nodes. With help of vice-CH, the collected information could reach to the sink even if CH dies.

GEAR

Use geographical information for distributing the queries to the appropriate regions.

Done the neighbour selection on the basis of energy and the location to route the packet.

conserves more energy than the Directed diffusion as forwarding region is restricted.

Each node keep account of two costs for reaching the destination :Estimated Cost, Learning Cost

Hole condition arise when a node does not have any neighbouring node to forward the packet further. In this condition the estimated cost is equal to the learned cost.

The algorithm consists of two phases:

- Routing towards destination region.
  - Nearest neighbour node to the destination region is selected as the next forwarding node.
  - In the hole's scenario, the neighbour node is selected on the basis of learning cost function.
- Data dissemination inside the destination region.
  - Uses restricted flooding or recursive geographic forwarding.

Literature Survey…

For underwater sensor networks, some of the existing energy efficient routing protocols are:

- Vector Based
- Cluster Based Protocol
- Distributed Underwater Clustering Scheme (DUCS)
- E-PULRP

VBF

Vector Based Forwarding protocol.

It is an energy efficient and robust algorithm.

A routing forwarding vector is defined between the source and the destination.

A forwarding region is defined around the routing vector consist of a predefined radius.

Only a set of nodes that are in forwarding region take part in routing.

An intermediate node will be the candidate of next relay node if the distance between itself and the ro*uting vector is less compared to the other nodes.*

Energy Efficient Cluster Based Protocol

This protocol utilizes the direction (up-down transmission) characteristic of underwater environment and shown to be a better performer in terms of whole network working.

It forms the clusters that are direction dependent. Cluster head is chosen in the direction of transmission only.

Cluster head collects the data from its cluster member and send the collected data to the sink via other cluster heads on the way.

DUCS

Distributed Underwater Clustering Scheme protocol.

An energy efficient and GPS-free routing protocol.

Clusters are formed inside the network and a cluster head is chosen.

Cluster head collects the data from its cluster's members in a single hop.

Multi-hop routing is used to transmit the data to sink from the cluster head.

Cluster head uses data aggregation technique to remove the redundant data from the collected information.

Uses TDMA/CDMA schedule to communicate with cluster members and to improve the communication as well.

Uses continuous adjusted timer along with the guard time vales to save the data loss.

E-PULRP

Energy optimized Path Unaware Layered Routing Protocol.

It is for dense underwater 3D sensor networks.

Up-link transmission is considered.

Underwater sensor nodes collect and send the information to the stationary sink node.

Consists of two phases layering phase and communication phase.

In the first phase a layering structure is developed around the sink node which is a set of concentric spheres. The radii of the concentric spheres as well as the transmission energy of the nodes in each layer are chosen considering probability of successful packet transmissions and minimum overall energy expenditure.

In the second phase an intermediate relay node is selected and on the fly routing algorithm is used for packet delivery from source node to sink node across the identified relay nodes.

Mobile Networks (SSWT ZG578)
Contact Session-12 ,13,14

WIRELESS WIDE AREA NETWORK

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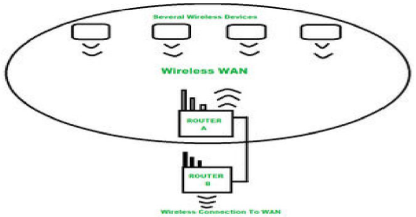
Contents

- Evolution of Cellular Networks
- Long-Term Evolution (LTE)
- LTE Architecture
- LTE Advanced
- 5G Networks Overview

Wireless Wide Area Network (WWAN)

- WWAN (Wireless Wide Area Network) is a WAN (Wide Area Network) and the only thing is that the connectivity is wireless
- . It provides regional, nationwide and global wireless coverage. Where Wide Area Network can be wired or wireless the Wireless Wide Area Network connections are completely wireless.
- In our day to day life we are using the Wireless Wide Area Network of different sizes and depending on it delivery of telephonic calls, Web pages and streaming video, data sharing occurs.
- WLAN (Wireless Local Area Network) differs from WWAN (Wireless Wide Area Network) technology wise for example when WLAN uses WiFi to connect and transfer data, WWAN uses telecommunication cellular network technologies such as 2G, 3G, 4G LTE, and 5G to transfer data.



In the above figure, several wireless devices are configured with the WLAN (Wireless Local Area Network) served by the Router-A and Router-B is a wireless router which connects to Router-A through ethernet and connected to the WAN (Wide Area Network) wirelessly flashed with DD-WRT.

Characteristics of WWAN :

- Reduced transmission speed as compared to physical connection.
- It is based on IEEE 802.16 standards.
- On increase of distance, decrease of throughput occurs and vice versa.
- Getting faster due to Gigabit-Class LTE.

Advantages of WWAN :

- Global wireless coverage
- Flexible with cloud management, deploying and relocating
- Better security than WLAN
- Diverse, cost effective backup for data applications.
- Quick deployment for new applications.

Disadvantages of WWAN :

- Replacement of lost WWAN may be costly.
- To maintain the reliable network connectivity.
- To build a cost effective solution is a challenge.
- Decreased throughput during large coverage area.

Application of Wireless Wide Area Network (WWAN):

1. Mobile correspondence
2. Fleet administration
3. Public security
4. Smart framework
5. Environmental checking

Evolution of Cellular Networks

With analysts forecasting 2.7 billion 5G connections by 2025, (Figure 1), the uptake of 5G is expected to be faster than any previous cellular generation and expectations are running high for its future impact on the global economy.

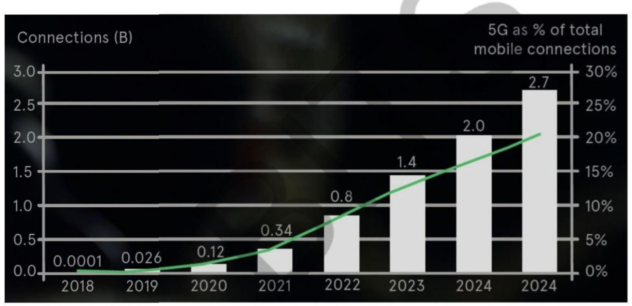


Figure 1: Forecast growth in global 5G connections (source: CCS Insight)

Generations

Since their initial arrival in the late 1970s, cellular networks and technology have evolved considerably, with successive generations, (2G through 4G) representing significant milestones in the development of mobile connectivity (Figure 2).

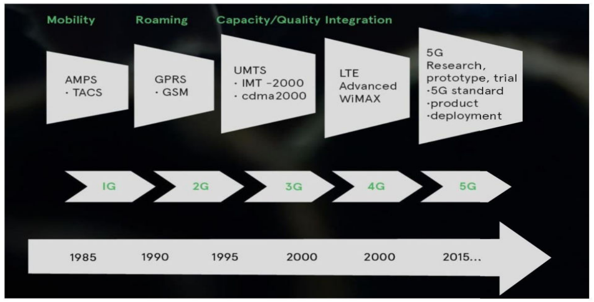


Figure 2: Cellular network evolution timeline (source: https://www.researchgate.net/fi gure/Mobile-Cellular-Network-Evolution-Timeline_fi g1_263657708)

First Generation

- Although not called 1G at the time, first generation mobile networks emerged in Japan in 1979, before rolling out to other countries such as the USA (1980), and the UK, (1985).
- Based on an analogue technology known as Advanced Mobile Phone System (AMPS), which used Frequency Division Multiple Access (FDMA) modulation, 1G networks offered a channel capacity of 30KHz and a speed of 2.4kbps.
- 1G networks only allowed voice calls to be made, suffered from reliability and signal interference issues and had limited protection against hackers.

Second Generation (2G)

- Despite its flaws the 1G network wasn't superseded until 1991, when 2G networks, were introduced.
- Based on digital signaling technology, Global System for Mobile Communication (GSM), which increased security and capacity, 2G networks offered bandwidths of 30KHz to 200KHz and allowed users to send SMS and MMS messages, although at low speeds, up to 64kbps.
- Continuous improvement of GSM technology led to the introduction of so-called 2.5G, which incorporated packet switching in the form of GPRS and also EDGE technology.
- 2.5G enabled data-rates up to 144kbps, enabling users to send and receive e-mail messages and browse the web.

- Third Generation (3G)
- The arrival in the year 2000 of 3G, known as UMTS in Europe and CDMA2000 in the USA, heralded a change in the way mobile phones were used and viewed by the end user, becoming less about voice calls, more about social connectivity.
- Also based on GSM, the main aim of 3G was to support high-speed data and the original 3G technology allowed data-rates up to 14Mbps.
- With its ability to transmit greater amounts of data at higher speeds, 3G enabled users to make video calls, surf the web, share files, play online games and even watch TV online.
- Whereas 2G networks would enable a 3-minute MP3 song to be downloaded in around 6-9 minutes, the same file would take anywhere between 11 and 90 seconds to download on a 3G network.
- Today the most common use for 3G networks is as a backup for 4G.

Fourth Generation (4G)

- The introduction of 4G really ushered in the era of the smartphone and hand-held mobile device.
- 4G is the first generation to use Long-Term Evolution (LTE) technology to deliver theoretical download speeds of between 10Mbps and 1Gbps, offering end users better latency (less buffering), improved voice quality, instant messaging services and social media, quality streaming and faster download speeds.
- 4G is also the first IP-based mobile network, handling voice as just another service and the technology is being developed to accommodate the Quality of Service (QoS) and rate requirements required by applications including wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB).
- Realising that 4G/LTE networks will ultimately reach capacity, the International Telecommunications Union, (ITU), in 2015, defined the requirements specification for 5G.

The 5G revolution

- The ITU specification for 5G, ITU-R IMT-2020 (5G), is summarised in Figure 3.
- The ambitious specification represents a step-change in performance over 4G and aims to address the requirements of the emerging applications, described above. Throughputs up to 10Gbps (100 times faster than 4G networks) aim to satisfy the growing hunger for bandwidth; latencies of 1mSec (cf. 30 - 50mSec for 4G) will enable near-real time response rates; and connection densities of 1000 devices per square kilometer (100 times more than 4G) will support the growing numbers of IoT devices and sensors.

The 5G revolution: Performance Indicators

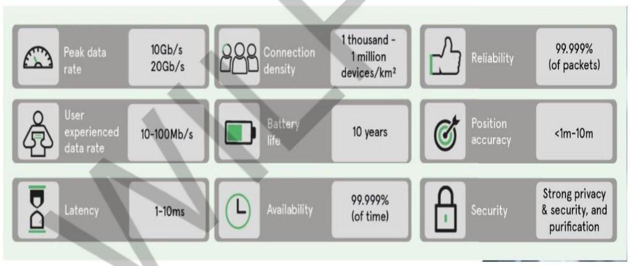
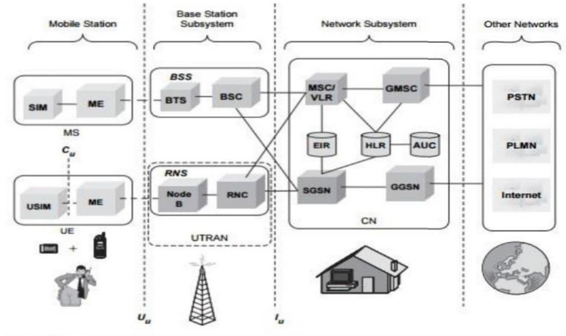


Figure 3: Selected key performance indicators of 5G according to ITU-R (source: "5G for Connected Industries and Automation", 2nd edition, White Paper, 5GACIA, November 2018)

UMTS NETWORK ARCHITECTURE – RELEASE 99

- The Universal Mobile Telecommunication System (UMTS) is a third generation (3G) wireless system that delivers high-bandwidth data and voice services to mobile users. UMTS evolved from GSM and has a new air interface based on Wideband Code division Multiple Access (WCDMA).
- Release 99 (R99) is the first version of UMTS architecture based on the new multiple access technology WCDMA for increased utilization of radio resources. The Third Generation Partnership Project (3GPP) has specified the R99 standards.



UMTS—3G reference architecture.

The major change is in the Radio Access Network (RAN) based on WCDMA and Asynchronous Mode of Transmission (ATM).
The UMTS architecture defines three main functional entities:
• User Equipment 9UE)
• UMTS Radio Access Network (UTRAN)
• Core Network (CN)
The Core Network (CN) which are again divided into 2 types.
• Circuit-Switched (CS) network
• Packet-Switched (PS) network

- **User Equipment:** UE replaces the MS (Mobile Station) for GSM/GPRS networks. A subscriber must buy a new handset for 3G services with a new SIM called USIM.
- USIM is a user subscription to the UMTS mobile network and contains all relevant data that enables access onto the subscripted network. The main difference between a USIM and GSM SIM is that by default, a USIM is downloadable and can be accessed via the air interface and be modified by the network. The USIM is a universal integrated service card having much more capacity than the GSM SIM. It can also store JAVA applications.

Node B

The base station used in UMTS is known as 'Node B' that replaces BTS. It provides that physical radio link between the UE and the network.. It is capable to handle CDMA subscriber on the new frequency bands.

It can also support higher data rates used for 3G. Node B is the termination point between the air interface and the transmission network of the RAN. IT performs the necessary signal processing functionalities for the WCDMA air interface and is more complex than BTS.

Node B is responsible for the following:

1. Power Control: It measures the actual signal-to-interference ratio (SIR), compares it with the threshold value and then may trigger the change of transmitting power of UE.
2. Reports the RNC (Radio Network Controller): The measured values are reported to RNC.
3. Combines the received signals coming from multiple sectors of the antenna that a UE is connected to: It converts the signals into a single data stream before it transmits to the RNC. This may help to soften the handover procedure for UMTS networks.

- Radio Network Controller
- The RNC is the main element in the Radio Network System (RNS) and controls the usage and reliability of radio resources. An RNC is similar to a BSC and is interfaced with the CS of a GSM core network (MSC) in order to handle circuit-switched calls along with SGSN for packet data transport.
- It also needs to be capable of supporting interconnections to other RNCs, which is a new feature of UMTS. The main tasks for RNC are call admission control, radio bearer management, power control and general management controls in connection to OMC (Operation Management Control).
- There are three types of RNCs:
  - 1. Serving RNC (SRNC)
  - 2. Drift RNC (DRNC)
  - 3. Controlling RNC (CRNC)

1. Serving RNC (SRNC)

The SRNC controls a user's mobility within a UTRAN. It is a connection point to the core network towards MSC or SGSN.

2. Drift RNC (DRNC)

The DRNC receives connected UEs that are drifted or handed over from the SRNC cell connected to a different RNS. The RRC (Radio Resource Controlled) is still connected to SRNC. The DRNC then exchanges the routing information between the SRNC and UE. Thus, the DRNC provides radio resources to the SRNC to allow soft handover.

3. Controlling RNC (CRNC)

CRNC controls, configures and manages an RNS and communicates with the Node B application part (NABP) protocol with the physical resources of all Node Bs connected via the Iu interfaces. Any access request from the UE is forwarded to the CRNC

LTE (Long-Term Evolution)

- LTE (Long-Term Evolution) is a fourth-generation (4G) wireless standard that provides increased network capacity and speed for cellphones and other cellular devices compared with third-generation (3G) technology.
- LTE is a technology for wireless broadband communication for mobile devices and is used by phone carriers to deliver wireless data to a consumer's phone. Over the previous iteration of 3G, LTE provided high speed, higher efficiency, peak data rates and flexibility in bandwidth and frequency.
- LTE offers higher peak data transfer rates than 3G, up to 100 Mbps downstream and 30 Mbps upstream. It provides reduced latency, scalable bandwidth capacity and backward compatibility with the existing Global System for Mobile communication (GSM) and Universal Mobile Telecommunications Service (UMTS) technology. The subsequent development of LTE-Advanced (LTE-A) yielded peak throughput on the order of 300 Mbps.

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- Although LTE is commonly referred to as 4G LTE, LTE is technically slower than 4G but still faster than normal 3G. For this reason, LTE may also be called 3.95G. While LTE speeds reach 100 Mbps, true 4G offers speeds up to 1,000 Mbps. However, different versions of LTE meet 4G speeds, such as LTE-A.
- LTE eventually became universally available as a standard that is still commonly available in areas that don't yet have 5G.
- LTE has a direct role in the development of the current 5G standard, called 5G New Radio. Early 5G networks, referred to as non-standalone 5G (NSA 5G), require a 4G LTE control plane to manage 5G data sessions. NSA 5G networks can be deployed and supported by the existing 4G network framework, lowering capital and operating expenses for operators rolling out 5G.

Why is LTE called Long-Term Evolution?

- The 3rd Generation Partnership Project (3GPP) developed LTE. The standard was described as the next step in the progression of mobile telecommunications as well as progression from the 2G GSM and 3G UMTS specifications. LTE is commonly marketed as 4G LTE.
- LTE did not originally qualify as true 4G. The International Telecommunication Union (ITU) initially defined 4G as a cellular standard that would deliver data rates of 1 Gbps to a stationary user and 100 Mbps to a user on the move. In December 2010, the ITU softened its stance, applying 4G to LTE, as well as several other wireless standards.

LTE NETWORK ARCHITECTURE

- In contrast to the circuit-switched model of previous cellular systems, Long Term Evolution (LTE) has been designed to support only packet-switched services. It aims to provide seamless Internet Protocol (IP) connectivity between user equipment (UE) and the packet data network (PDN), without any disruption to the end users' applications during mobility.
- While the term "LTE" encompasses the evolution of the Universal Mobile Telecommunications System (UMTS) radio access through the Evolved UTRAN (EUTRAN), it is accompanied by an evolution of the non-radio aspects under the term "System Architecture Evolution" (SAE), which includes the Evolved Packet Core (EPC) network. Together LTE and SAE comprise the Evolved Packet System (EPS).
- EPS uses the concept of EPS bearers to route IP traffic from a gateway in the PDN to the UE. A bearer is an IP packet flow with a defined quality of service (QoS) between the gateway and the UE. The E-UTRAN and EPC together set up and release bearers as required by applications

- EPS provides the user with IP connectivity to a PDN for accessing the Internet, as well as for running services such as Voice over IP (VoIP).
- An EPS bearer is typically associated with a QoS. Multiple bearers can be established for a user in order to provide different QoS streams or connectivity to different PDNs.
- For example, a user might be engaged in a voice (VoIP) call while at the same time performing web browsing or FTP download.
- A VoIP bearer would provide the necessary QoS for the voice call, while a best-effort bearer would be suitable for the web browsing or FTP session.

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The high-level network architecture of LTE is comprised of following three main components:

- User Equipment (UE)
- Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
- Evolved Packet Core (EPC).

The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem. The interfaces between the different parts of the system are denoted Uu, S1 and SGi as shown below

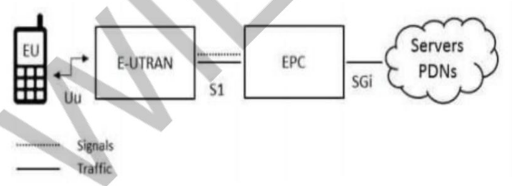

Fig: The LTE network Architecture

(i) **User Equipment (UE):** The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment (ME).

The mobile equipment comprised of the following important modules:

- Mobile Termination (MT): This handles all the communication functions.
- Terminal Equipment (TE): This terminates the data streams.
- Universal Integrated Circuit Card (UICC): This is also known as the SIM card for LTE equipment's. It runs an application known as the Universal Subscriber Identity Module (USIM).

A **USIM** stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

(ii) **E-UTRAN** (The access network) The architecture of evolved UMTS Terrestrial Radio Access Network (EUTRAN) has been illustrated below:

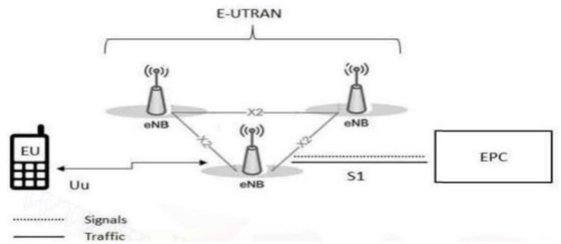

Fig: The architecture of E-UTRAN

- The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called eNodeB or eNB.
- Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB.

LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB:

- ➢ The eBN sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.
- ➢ The eNB controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.

- Each eBN connects with the EPC by means of the S1 interface and it can also be connected to nearby base stations by the X2 interface, which is mainly used for signaling and packet forwarding during handover.
- A home eNB (HeNB) is a base station that has been purchased by a user to provide femtocell coverage within the home. A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

(iii)Evolved Packet Core (EPC) (The core network): The architecture of Evolved Packet Core (EPC) has been illustrated below.

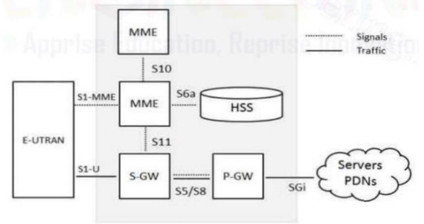

Fig: The architecture of Evolved Packet Core

There are few more components which have not been shown in the diagram to keep it simple. These components are like the Earthquake and Tsunami Warning System (ETWS), the Equipment Identity Register (EIR) and Policy Control and Charging Rules Function (PCRF).

Below is a brief description of each of the components shown in the above architecture:

- The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.
- The Packet Data Network (PDN) Gateway (P-GW) communicates with the• outside world ie. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.
- The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.

- The mobility management entity (MME) controls the high-level operation of the mobile by means of signaling messages and Home Subscriber Server (HSS).
- The Policy Control and Charging Rules Function (PCRF) is a component which is not shown in the above diagram but it is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW.

The interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different networks.

LTE PROTOCOL STACK LAYER

Physical Layer (Layer 1)

Physical Layer carries all information from the MAC transport channels over the air interface. Takes care of the link adaptation (AMC), power control, cell search (for initial synchronization and handover purposes) and other measurements (inside the LTE system and between systems) for the RRC layer.

Medium Access Layer (MAC)

MAC layer is responsible for Mapping between logical channels and transport channels, Multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels, demultiplexing of MAC SDUs from one or different logical channels from transport blocks (TB) delivered from the physical layer on transport channels, Scheduling information reporting, Error correction through HARQ, Priority handling between UEs by means of dynamic scheduling, Priority handling between logical channels of one UE, Logical Channel prioritization.

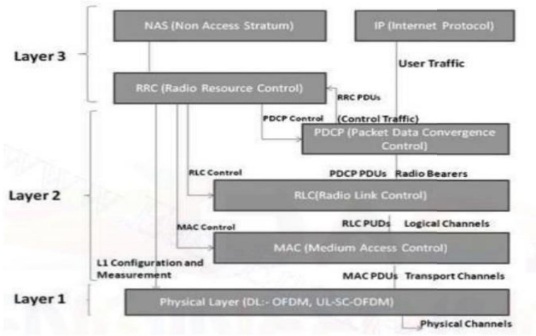

Fig: E-UTRAN Protocol Stack

Radio Link Control (RLC)

- RLC operates in 3 modes of operation:
  - • Transparent Mode (TM)
  - • Unacknowledged Mode (UM)
  - • Acknowledged Mode (AM)
- RLC Layer is responsible for transfer of upper layer PDUs, error correction through ARQ (Only for AM data transfer), Concatenation, segmentation and reassembly of RLC SDUs (Only for UM and AM data transfer).
- RLC is also responsible for re-segmentation of RLC data PDUs (Only for AM data transfer), reordering of RLC data PDUs (Only for UM and AM data transfer), duplicate detection (Only for UM and AM data transfer), RLC SDU discard (Only for UM and AM data transfer), RLC re-establishment, and protocol error detection (Only for AM data transfer).

Radio Resource Control (RRC)

The main services and functions of the RRC sublayer include broadcast of System Information related to the non-access stratum (NAS), broadcast of System Information related to the access stratum (AS), Paging, establishment, maintenance and release of an RRC connection between the UE and E-UTRAN, Security functions including key management, establishment, configuration, maintenance and release of point to point Radio Bearers.

Packet Data Convergence Control (PDCP)

PDCP Layer is responsible for Header compression and decompression of IP data, Transfer of data (user plane or control plane), Maintenance of PDCP Sequence Numbers (SNs), In-sequence delivery of upper layer PDUs at re-establishment of lower layers, Duplicate elimination of lower layer SDUs at re-establishment of lower layers for radio bearers mapped on RLC AM, Ciphering and deciphering of user plane data and control plane data, Integrity protection and integrity verification of control plane data, Timer based discard, duplicate discarding, PDCP is used for SRBs and DRBs mapped on DCCH and DTCH type of logical channels.

Non Access Stratum (NAS) Protocols

The non-access stratum (NAS) protocols form the highest stratum of the control plane between the user equipment (UE) and MME. NAS protocols support the mobility of the UE and the session management procedures to establish and maintain IP connectivity between the UE and a PDN GW

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5G Networks Overview

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5G Wireless Technology

- Introduction to 5G
- Evolution from 1G to 5G
- Key concepts
- Architecture
- Hardware & Software of 5G
- Features
- Advantages
- Applications
- Conclusion

What is 5G?

5G Wireless: 5th generation wireless technology
Complete wireless communication with almost no limitations
Can be called REAL wireless world
Has incredible transmission speed
Concept is only theory not real

What does it offer?

Worldwide cellular phones
Extraordinary data capabilities
High connectivity
More power & features in hand held phones
Large phone memory, more dialing speed, more clarity in audio & video

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5G technology is the latest telecommunication network that is designed after 1G, 2G, 3G and 4G networks.

It is the 5th generation mobile network.

It is designed to connect virtually in high data speed, with high reliability and low latency.

5G is a unified platform than 4G.

5G can deliver up to 20 Gigabits-per-second (Gbps) peak data rates and 100+ Megabits-per-second (Mbps) average data rates.

Where can be 5G used?

5G can be used in three main connection service, they include:

- Enhanced Mobile Broadband
- Mission-critical communications, and
- The massive IoT

It is designed to support the services flexibly that will be necessary in future.

5G mobile technology can be used in smartphones with faster and uniform data rates with low cost per bit.

5G offers industries low latency links for performing remote control over infrastructure, vehicles and medical uses.

Is 5G Hazard to health ?

In spite of abundant benefits gained by uses, 5G technology radiations also carries various health hazards to living beings.

The cell towers may use high frequency signals to get large amount data. It also requires many cell towers. Experts claim that health worse off in persons residing near mobile towers.

The electromagnetic force cause inflammations, disrupting the circadian rhythm of organic living beings.

It may also cause heart problems, dizziness, nausea, anxiety and depression.

Also researches have predicted that the radiations penetrates into tissues and affect the nervous system. It also causes skin diseases including cancers in prolonged use.

Despite humans, the electromagnetic radiations also cause impacts in birds and their nesting behaviour, in growth of trees and plants. And cause impact in natural habitat.

Is 5G Boon or Bane ?

The telecommunication companies claim to provide faster internet and the user demand over bandwidth.

Rural areas would also get internet service.

5G technology requires small cell towers to be deployed closer to users with more antennas to expand its data-intensive coverage.

There are possibilities that 5G networks are more hack-able because it's connected and integrated.

Although there are various confusions over the need, safety, and efficiency of 5G network various countries have declared the technology as safe and implemented.

It is also ready to hit the market.

Advantages of 5G Technology

5G is designed to connect numerous embedded sensors virtually in low data, power and mobility.

5G technology works 10 times faster than 4G and so it is easier to download files/ videos just in seconds.

Data rates of 5Gbps or more can be achieved.

Decreases traffic load.

Provides consistent and uninterrupted connectivity through the world.

5G provides 10 times decrease in latency.

It is manageable with previous generations.

It can give 3 times more spectrum efficiency.

Disadvantages of 5G Technology

5G equipment's are costly to install and maintain.
5G smartphones are costly for common man to use.
Privacy issues are not yet resolved.
5G waves may suffer in losses in penetration, attenuation due to rain, etc.,

Key Concepts

- Real wireless world with no more limitations with access & zone issues
- Wearable devices
- IPv6, where a visiting care of mobile IP address is assigned according to location & connected network
- One unified global standard
- Smart radio
- The user can simultaneously be connected with several wireless access technology
- Multiple concurrent data transfer path

Basic Architecture of 5G

Application Layer	Application(Service)
Presentation layer	
Session Layer	Open Transport Protocol (OTP)
Transport Layer	
Network Layer	Upper network layer
	Lower network layer
Datalink Layer	Open Wireless Architecture (OWA)
Physical Layer	