SAKARYA ÜNİVERSİTESİ
Bilgisayar ve Bilişim Bilimleri Fakültesi
Bilgisayar Mühendisliği Bölümü

BSM 451
INTERNET OF THINGS AND APPLICATIONS

IoT Wireless Communication Technologies
Cellular Long-Range

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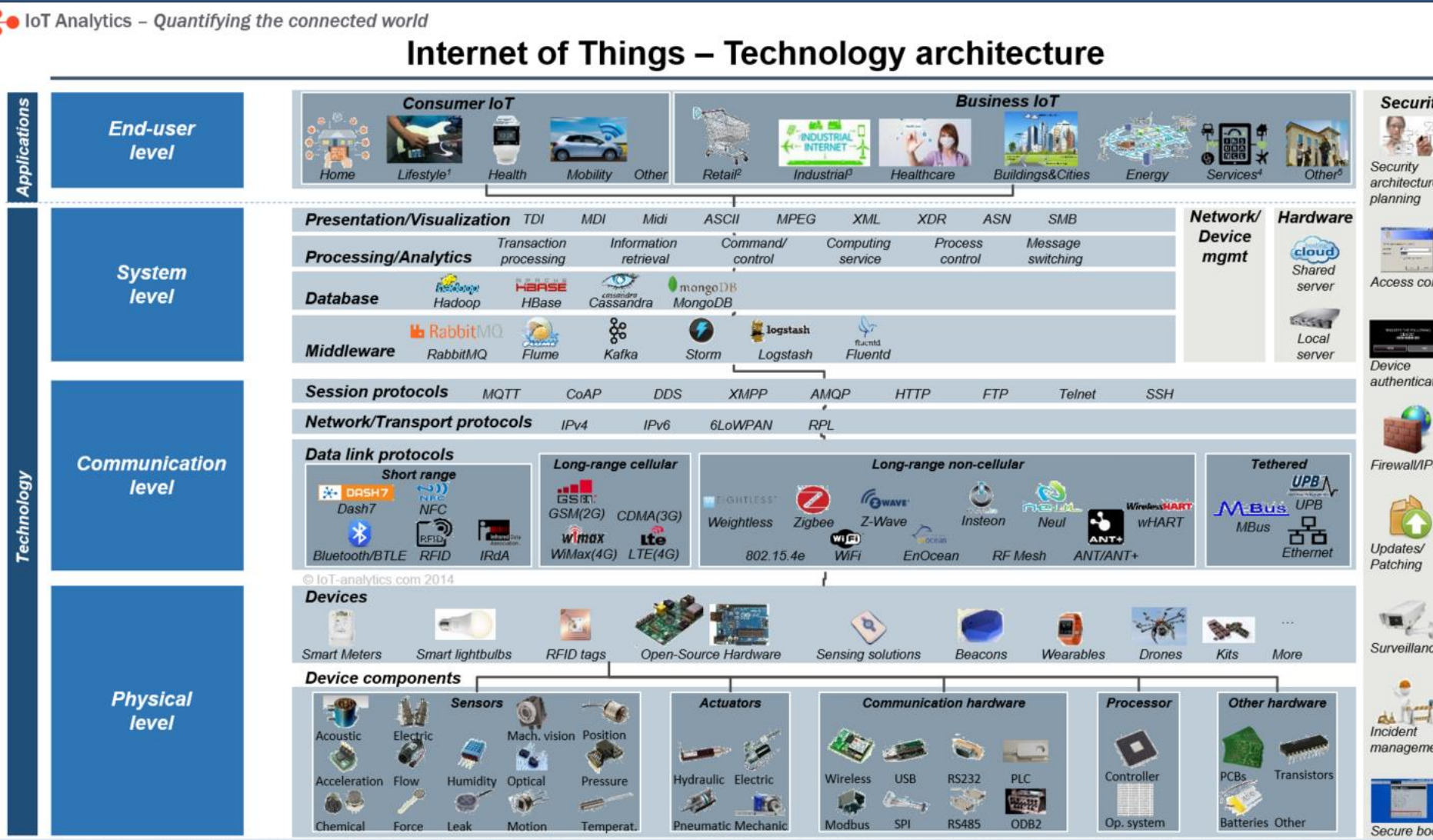
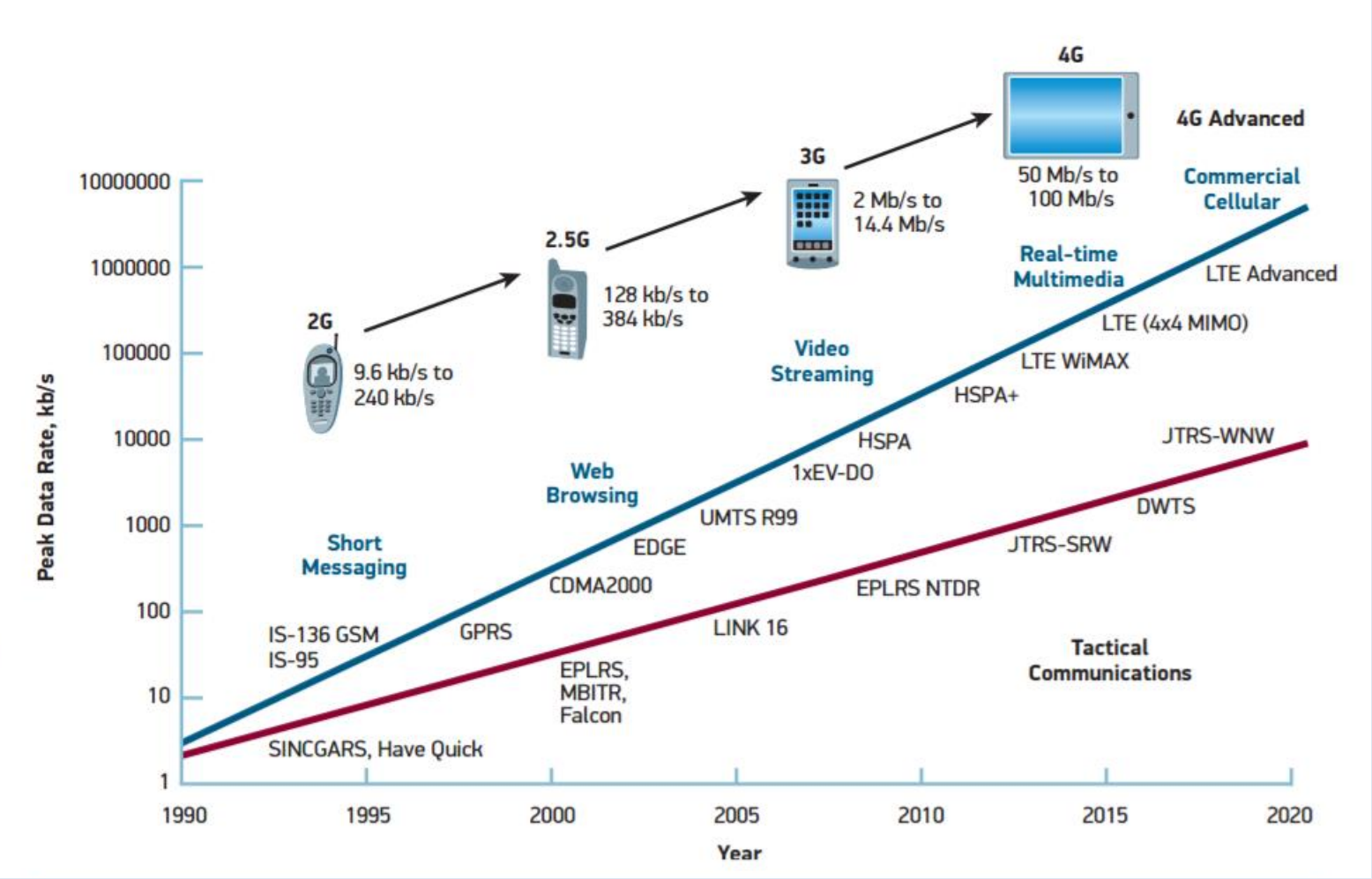
IoT Technology Architecture



IoT Wireless Communication Technologies

- Short Range
  - Radio-Frequency Identification, RFID,
  - Near Field Communications, NFC,
  - Bluetooth Low Energy (BLE),
  - Infrared (IRdA)
- Non-Cellular Long-Range
  - Wireless Sensor Networks (IEEE 802.15.4 - ZigBee),
  - Z-Wave
  - ANT/ANT+
- **Cellular Long-Range**
  - **GSM / GPRS**
  - **3G / 4G (LTE) / 4.5G (LTE Advanced)**
  - **WiMAX**

Evolution of Cellular Mobile Networks



Source: H. Jensen, J. Sharpe, ‘‘LTE Infrastructure for Command and Control Networks’’, http://www.radisys.com/sites/default/files/paper-lte-infrastructure-for-cc.pdf

Classification of Cellular Mobile Networks

	1G	2G	2.5G/2.75G	3G	4G	4.5G	5G
Teknoloji	Analog hücresel	Sayısal Hücresel	Sayısal Devre Anahtarlamalı Veri	Genişbant, CDMA/IP teknoloji	Birleşik IP, LAN,WAN,WLAN birleştirilmesi	4G + WiFi	4G + wwww
Servis	Yalnızca ses, Mobil telefon	Sayısal ses, kısa mesajlaşma	Ses ve veri iletimi	Yüksek kaliteli ses, video ve data	Dinamik veri iletişimi, cihaz çeşitliliği	Dinamik veri iletişimi, arttırılmış kapasite ile cihaz çeşitliliği	Dinamik veri iletişimi, yüksek kapasite ile cihaz çeşitliliği
Çoğullama	FDMA	TDMA/CDMA	TDMA	CDMA	CDMA	CDMA	CDMA
Ağ	PSTN	PSTN	PSTN / Paket ağ	Paket ağ	İnternet	İnternet	İnternet
Veri İletim Hızı	2 Kbit/s	14-64 Kbit/s	384 Kbit/s	2 Mbit/s	100 Mbit/s	450 Mbit/s	1Gbit/s ve üzeri
Standartlar	AMPS, NMT, TACS, C-450	GSM	GPRS, HSCSD, EDGE	WCDMA, CDMA2000 UMTS, HSDPA	WiMAX, LTE	LTE Advanced IMT Advanced	Femtocell

Source: H. Jensen, J. Sharpe, ‘‘LTE Infrastructure for Command and Control Networks’’, http://www.radisys.com/sites/default/files/paper-lte-infrastructure-for-cc.pdf

General Packet Radio Service (GPRS)

- A standard used for communication over cellular networks.
- Mostly known as 2.5G technology.
- It uses pacekt switching that has many advatages for a wireless mobile user interested in data communication.
- It provides following features from network operator's perspective;
  - IPv4 and IPv6
  - WAP (Wireless Application Protocol)
    - ✓ Provides internet content on mobile phones and PDAs.
  - Data rate: 56–114 kbit/s
  - Each user is assigned to 8 channels or each channel is assigned to 16 users.

Enhanced Data Rates for Global Evolution

- **EDGE** is a radio interface that uses 8-Phase Shift Keying (8-PSK) modulation technique, which is more efficient than Gaussian Prefiltered Minimum Shift Keying (GMSK) used in GSM.
- **EDGE** has the potential of triple the data rate used in previous GSM technology.
- Similar to GPRS, each user is assigned to 8 channels.
- Each channel can carry 48Kbps data and EDGE reaches data rate of 384 Kbps.
- **GSM** Since it uses the same TDMA frame structure and existing cellular settings of GSM, EDGE can be setup over an existing GSM network by just adding EDGE trasceivers.

3G

- It is defined as under the International Mobile Telecommunications, IMT2000 frame by ITU.
- Faster data transmission and larger bandwidths has become available with third generation system..
- As 1G and 2G, it uses cellular network system.
- The standardization of 3G is handled by two organizations.
  - Third Generation Partnership Project (3GPP)
    - ✓ Works on standards based on GSM-oriented networks.
  - 3GPP2
    - ✓ Works on standards based on IS-95 (a.k.a. CDMA2000)-based 3G technology.

3G

New features brought by 3G:

- Instant messaging, internet access and multi-access communication support in high data rates,
- Advanced quality of service,
- Advanced battery life,
- Location services,
- Easy on operation and maintenance,
- Interoperability with existing networks, converting back to 2G,
- Low setup cost,
- Due to its advanced security methods, mobile-commerce is available,

4G

- ITU defined International Mobile Telecommunications-Advanced, IMT-A as 4G.
- IPv6-based communication technology.
- 4G standards are developed by three organizations.
  - IEEE, 802.16m (WiMAX2)
  - 3GPP, LTE-Advanced (Long Term Evolution)
  - 3GPP2 , UMB (Ultra Mobile Broadband)

4G is completely integrated with IP.

Aiming high data rate, high security, and high quality of service for any type of network anytime anywhere.

WiMAX

- WiMAX (Worldwide Interoperability for Microwave Access) technology is wideband wireless technology that supports fixed, portable, and mobile access.
- **IEEE 802.16** standards.
- Can carry voice, data, and video with high security and quality of service in 75 Mbps data rate within 50 km coverage area..
- It works on 2, 6, 10, 11, 66 GHz spectrums that varies depending on the version.
- First standars was introduced in October 2001 and worked as Line-of-Sight (LoS). Later standards (802.16a, d, e) worked as Non Light-of-Sight (NLoS).
- IEEE 802.16e version provides mobile wireless wideband communication.
- IEEE 802.16m standard is defined as a 4G technology (WiMAX 2).
- 802.16m standard supports 360 Mbps data rate.

WiMAX Applications

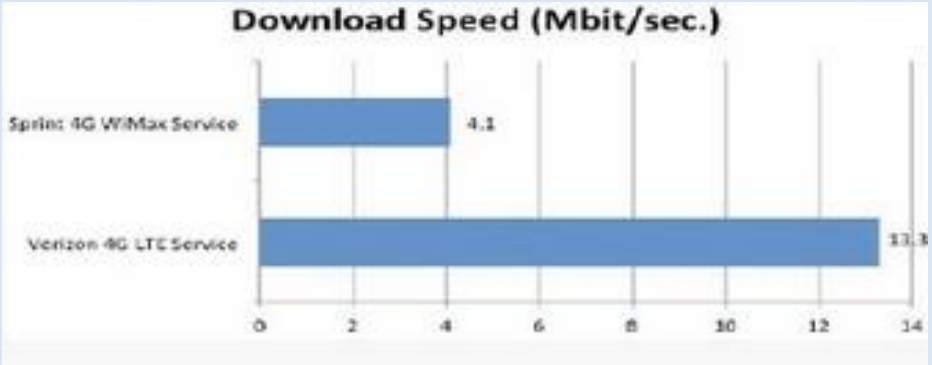
Defense		✓*Wideband and connecting remote units to command center (netcentric warfare applications)* ✓*Surveillance System Connections*
Energy		✓*Remote Monitoring and Management Applications* ✓*GRID Applications, tele-protection & personnel mobility applications, telemetry solutions*
Public Security		✓*Surveillance and tracking Systems, City Management, Camera Systems* ✓*Post-disaster communication systems* 
Institutional		✓ *Increasing efficiency by Wideband mobility applications* ✓*Wideband access connection to remote work stations*
Public Sector		✓*Over breaching "Digital Bridge" in a cost-efficient way* ✓*Providing wideband access infrastructure to E-State, E-Learning, and E-Health projects and programs*
Transportation		✓*Video surveillance, e-ticket, internet access…* ✓*Baggage and cargo tracking and management, Personnel Mobility…*

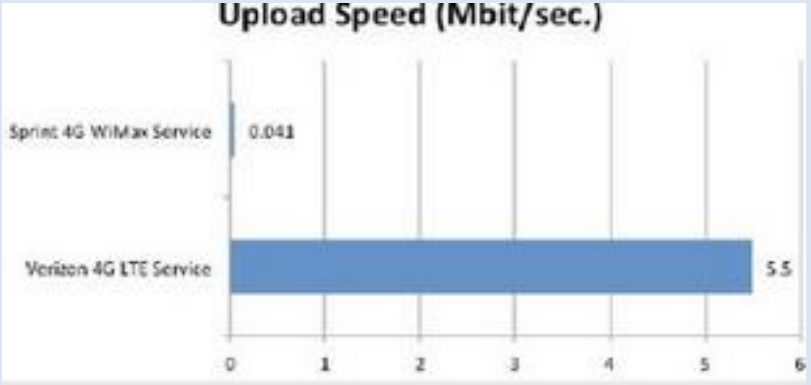
Long Term Evolution (LTE)

- Accepted as 4G mobile communication standard by 3GPP.
- The most important features of LTE are high capacity and high data transfer rate.
- Ericsson did the first mobile call over LTE in 2008.
- First open-public LTE service was deployed in Oslo and Stockholm by Telia Sonera in 2009.
- Features of LTE technology
  - High data rates (DL: 100 Mbit/s, UL: 50 Mbit/s),
  - Low latency (transmission time <10ms, setup time < 100ms),
  - High capacity (200 users in 5 MHz, 400 users in wider spectrum),
  - IP-based flexible spectrum usage,
  - Cellular coverage support upto 5-100 km,
  - 1.25, 2.5, 5, 10, 15 ve 20 MHz bandwidth support,
  - Mobility support upto 500 kmph speed,

WiMAX vs. LTE

- A test was conducted in 10 different places of New York City in US to compare Verizon LTE network and Sprint WiMAX network.
- Verizon LTE works in 700 MHz and theoretically supports 100 Mbps data rate.
- Sprint WiMAX works in 2.5 GHz and theoretically supports 128 Mbps data rate.





- ✓ WiMAX reaches max. 11.2 Mbps, while LTE reaches 26.1 Mbps.
- ✓ LTE is 3 times faster than WiMAX on average.
- ✓ For a video uploaded to Youtube, WiMAX reaches 41 Kbps on avearge, while LTE reaches 5.5 Mbps on average.

4.5G

- 4.5G was introduced in our country in April 2009.
- Definitions of 4G and 4.5G technologies varies between countries and institutions. For example, IMT-Advanced (LTE-Advanced) can be accepted as 4.5G.
- The advantages of 4.5G
  - Bandwidth (Use of 390.4 MHz bandwidth use on 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, and 2600 MHz frequency bands),
  - High data rate (theoretically 450 Mbps),
  - High performance (mobil tv, high quality video chat, etc.),
  - From operators' and service providers' perpective, it can provide high network throughput, use of new frequency bands, low costs, support for all IP versions, ease of management, etc.

Developing IoT-Based Applications with Cellular Long-Range Wireless Technologies

AT Command Set

- AT (short for 'ATtention') command set is a standard developed by 'Hayes' Telecommunication Co.
- AT Command Set used not only for GSM/GPRS, but also for communication of devices such as fax, modem, WiFi ICs (ESP8266, etc.).
- All commands start with 'AT'. AT, by itself, is not a command, but it is beginning of a command.
- Example: Dialling command
  - ATD+905xxxxxxxx;
- Approx. 4 seconds after sending each AT command, a Result Code is received.
- In AT command set, the commands starts with + are expanded commands. Basic commands such as Dial (D), Answer (A) do not start with + sign.
- Example: SMS command
  - AT+CMGS = \ "+905xxxxxxxx \"

AT Command Set Examples

Command	Description
AT + command=?	Verifies whether an AT command is supported or not.
ATA	Accepts an incoming call.
ATD+905xxxxxxxx	Dialling a number
ATH	Terminates an active call
AT+CMGF=1	Applies text format to sent or received SMS (Standard format is Hex)
AT+CMGS = \‘‘+905xxxxxxxx \’’	After this command, the text to be sent is added and Ctrl+Z (ascii 26) is added to the end to tell the message is over.
AT+CMGR=1	Reading a received message (info about the message –phone number, name, date are read along with message content)
AT+CMGD	Erase SMS = 0 erase a certain message (index number is given), = 1 erase all read messages = 4 erase all unread messages

AT Command Set Examples

Komut	Açıklama
AT + CIMI	IMSI query
AT + CGSN	IMEI query
AT + CPIN = ‘‘<pin>’’	Entering Pin
AT + CSQ	Signal strength query (between 0 and 31.99)
AT+SAPBR AT+SAPBR=3,1, "Contype", "GPRS" AT+SAPBR=3,1, "APN", "CMNET" AT+SAPBR=1,1 AT+SAPBR=2,1	Setup a connection with GPRS Select GPRS as connection type Setup access point (APN) (WWW instead of CMNET) Authenticate GPRS If connection is setup properly and an IP address is returned, it runs
AT+HTTPINIT AT+HTTPPARA= "CID", 1 AT+HTTPPARA="URL", "http://www.sakarya.edu.tr/test.html" AT+HTTPACTION=0 AT+HTTPREAD AT+HTTPTERM	Start HTTP mode Setup HTTP Address of web site to be accessed Start HTTP GET session Read the data received Terminate HTTP session.

GPRS Module Examples Used in IoT Applications

- Four different band support (850/ 900 / 1800 / 1900 MHz)
- GPRS multi-slot class 10/8
- GPRS mobile station class B
- Control with AT commands
- SMS
- Embedded TCP/UDP stack (data upload to web server)
- Real-Time Clock (RTC)
- Selective serial port
- Speaker and headphone port
- Low power consumption (sleep mode 1.5 mA)
- Running Temperature (between - 40 C and + 85 C)

- Four different band support (850/900/1800/1900MHz)
- GPRS multi-slot class 12
- GPRS mobile station class B
- Control with AT commands
- SMS
- Embedded Internet service protocols, multi-scokets, IP add.
- Jammer sensing
- Low power consumption (1.3 mA)
- Running temprature (between - 40 C and + 85 C)

Global Navigation Satellite Systems (GNSS)

- GNSS is a generic name for localization (navigation) systems with satellites.
- A GNSS receiver can compute the lattitude, longitude, and height of its location and local time at the location.
- GNSS is used for localization of land, aero, marine vehicles, vehicle tracking systems, geodesic-oriented measurements, etc.
- GNSS Systems
  - GPS (A.B.D.)
  - GALILEO (Avrupa Birliği)
  - GLONASS (Rusya)
  - BEIDOU/COMPASS (Çin)
  - QZSS (Japonya)
  - IRNSS/GAGAN (Hindistan)

Global Positioning System (GPS)

- GPS is USA's localization system with satellites.
- 31 satellites that orbits Earth (1 round in 12 hours).
- Minimum four and maximum 12 satellite can be seen at any time.
- All satellites broadcast in two signals: 1,57542 GHz (L1 signal) and 1,2276 GHz (L2 signal).
- GPS system consists of three components: satellites (space component), control (earth stations), and users (GPS receivers).

GPS Module Examples Used in IoT Applications

- 22 tracking/66 acquisition channel GPS receiver
- Update rate 10 Hz
- Serial Interface Support (UART, SPI, I2C)
- Digital I/O (GPIO)
- Power Consumption: (standby <200uA, tracking 19 mA)

- 50 channel GPS receiver
- Update rate 5 Hz (Neo-6M)
- Sensitivity 5 m
- Serial Interface Support (UART, SPI, I2C)
- Power Consumption: (standby <22 mA)

Ardunio GSM-GPS Shield

- Specifications
  - ✓ SIM900 GSM Module
  - ✓ SIM28 GPS Module
  - ✓ Serial Interface Support (UART, SPI, I2C)
  - ✓ Digital I/O (GPIO)
- Applications
  - ✓ M2M Applications
  - ✓ GSM activities (Dialling, SMS, etc.)
  - ✓ Remote device tracking and control
  - ✓ Scada – Telemetry applications

Source: http://www.gndteknik.com/gndkits/arduino/gsm-gps-shield

References

- Doç. Dr. Cüneyt BAYILMIŞ, ‘Kablosuz Ağ Teknolojileri ve Uygulamaları’ Ders Notları, 2016.
- Andreas F. Molisch, “Wireless Communications”, Wiley, 2005
- AT Komut Test Yazılımı, http://m2msupport.net/m2msupport/module-tester/
- G. Boysen "Mobile Communications-Data transmission in industry", Phoenix Contact, 2012.
- V. Marttin, C. Bayılmış, U. Yüzgeç, "Yeni Nesil Mobil Kablosuz Ağlar: 4.5G Üzerine Bir Araştırma", Uluslararası Bilgisayar Bilimleri ve Mühendisliği Konferansı (UBMK2016), 666-670, Tekirdağ, Türkiye, 20-23 Ekim 2016.
- H. Jensen, J. Sharpe, ‘‘LTE Infrastructure for Command and Control Networks’’, http://www.radisys.com/sites/default/files/paper-lte-infrastructure-for-cc.pdf
- GND Teknik, http://www.gndteknik.com/
- SIMCOM, http://www.simcom.eu/
- http://www.3gpp.org/
- http://www.3gpp2.org/