EE 542: USC Fall 2017
Sept. 25, 27, 2017

Prof. Kai Hwang, EEB 212
kaihwang@usc.edu

Lecture 10: Big Data and IoT Sensing Technologies and Devices
Reading: Sections 2.1 and 2.2 in Chap. 2

Lecture 11: Cloud Analytics and IoT Interactions
Reading: Sections 2.3.3~2.3.4 in Chap. 2
(Sec. 2.4 is skipped until a later lecture)

EE 542 Home Work Set #2, Due Oct.9, 2017, (6%)

Chapter 2: Prob. 2.4, Prob.2.5, Prob.2.13 (Lectures 10 and 11)

Chapter 5: Prob. 5.1, Prob.5.5, Prob.5.7 (Lectures 12, 13)

Chapter 8: Prob. 8.3, Prob. 8.4, Prob. 8.5, Prob.8.8, Prob. 8.11, Prob. 8.14 (Lectures 7, 8)

Those programming problems in Chapter 8 may take longer time to run successfully on the AWS. Start the work now.

The Five V's of Big Data

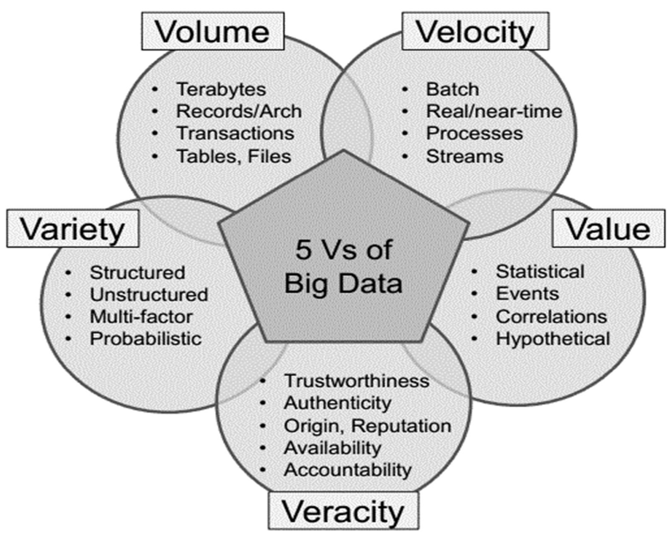


Table 2.2
Evolution of the big data industry in three development stages.

Stage	Databases	Data Centers	Big Data Industry
Time Frame	1960–1990	1980–2010	2010 and beyond
Data Sizes	MB, GB, TB	TB, PB, EB	EB, ZB, YB
Market Size and Growth Rate	Database market, data/knowledge engineering	$22.6 billion market by IDC 2012; 21.5% growth	$34 billion in IT spending (2013), predicted to exceed $100 billion by 2020; 4.4 million new big data jobs (2015)

Table 2.5
IoT value chain among major players and estimated value share.

Objects or Users	Sample Objects, Users, Operators, Providers, Distributors, or Customers	Estimated Share
Building Components	Embedded chips, modules, wireless modems, sensors, cameras, routers, gateways, antennas, and cables	5–10%
Smart Objects	Smart bins, solar cells, temp sensor, fire extinguisher, meters, ATM, cameras	
Network Operators	Spectrum allocation, network infrastructure, connectivity, availability, billing, customer services	15–20%
Service Enablers	Software, infrastructure, technology selection, consulting, solution design	30–40%
System Integrators	Interfaces, enterprise system integration, app development, security, data management, hardware and installation	15–20%
Service Providers	Analysis, app managers, access control, data managers, QoS, service provision	15–20%
Distributors/Resellers	Product distribution, road services, forward supply chains	Unknown
Clients or Customers	Buyer service and user services	Unknown

Today's Big Data Software Libraries

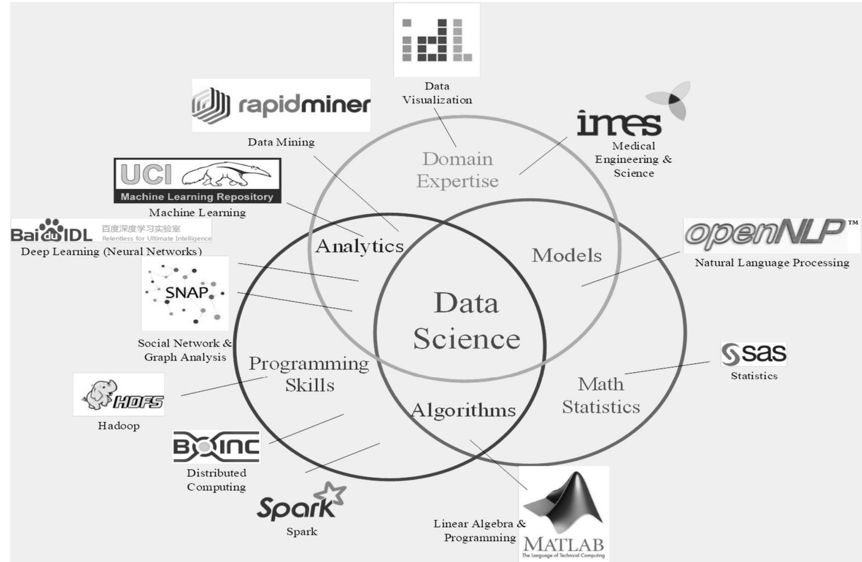
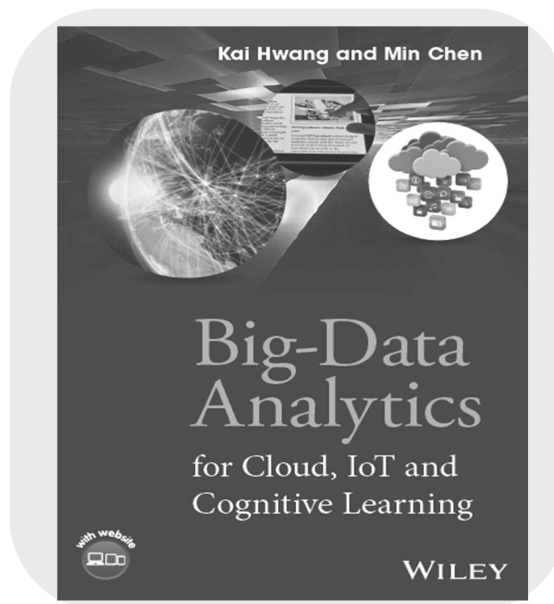


Table 2.3
Software libraries for cloud and cognitive computing over big data sets.

Category	Software	Brief Description	Web Link
Big Data Analytics	Apache Mahout	Scalable machine learning for data analytics, clustering, and classification	Mahout.apache.org
	RapidMiner	Data mining and predictive analytics	Rapidminer.com
	PaddlePaddle	Baidu deep learning for intelligence	Paddlepaddle.org
	SNAP	Stanford network analysis platform with graph mining library	Snap.stanford.edu
Mathematic/ Statistical Modeling	OpenNLP	Java machine learning toolkit for natural language processing	Opennlp.org/projects
	SAS	SAS software—statistics for mining, analytics, and data management	sas.com
	Bayesian Classifier	Statistical decision theory for data classification and prediction	En.wikipedia/org/wiki/ Naïve_Bayes_classifier
Algorithms	MATLAB	Linear algebra and matrix manipulation	mathworks.com/produsts/matlab
	Graphstream	Open-source dynamic graph analysis	graphstream-project.org
Programming Tools	Hadoop	Java-implemented MapReduce library	Hadoop.apache.org
	Spark	Scalable computing with DAG model	Spark.apache.org
	HDFS	Hadoop distributed file system	Hadoop.apache.org
	BOINC	Berkeley open infrastructure for network computing	Github.com/BOINC/boinc
	TensorFlow	Deep learning with neural networks	tensorflow.org
App Domain Expertise	X Lab	Google research for disruptive technology and smart machines	solveforx.com
	IMES	MIT Institute for Medical Engineering and Science	Imes.mit.edu



A new book coauthored by Hwang and Chen.

Part of the work was carried out during Dr. Chen's academic visit USC/MHI in 2016

MHI Emerging Trends Seminar, Kai Hwang, USC, 04/26/2017

EE 542, Lectures 22, 23 and 24

November 16, 18, and 23, 2015

The Internet of Things (IoT)

(Chap.9 and Handout Papers)

Prof. Kai Hwang, USC

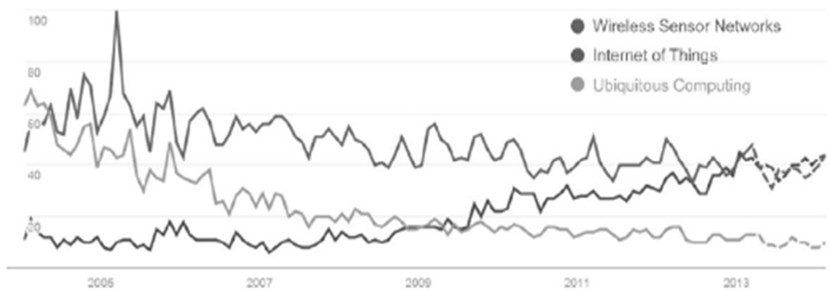


Fig. 3. Google search trends since 2004 for terms Internet of Things, Wireless Sensor Networks, Ubiquitous Computing.

Evolution of The Internet of Things

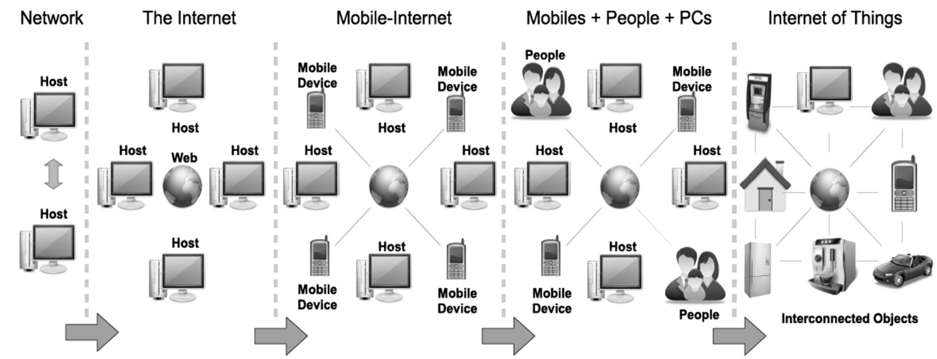
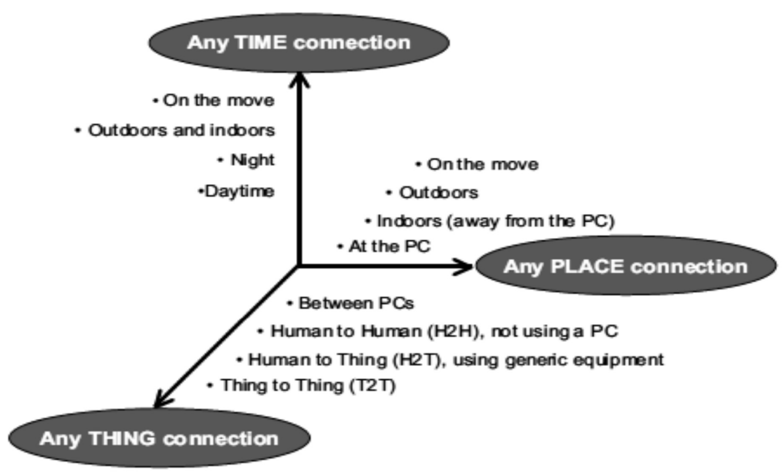


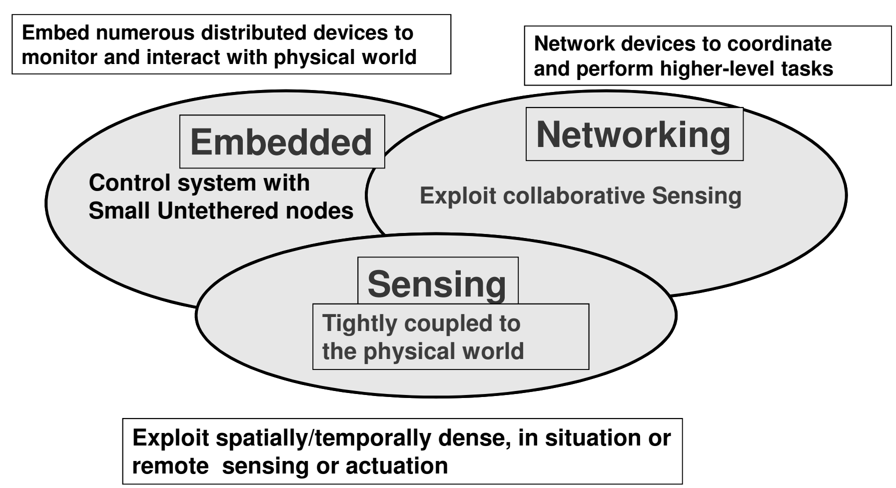
Figure 4.10 Evolution of the Internet in five phases. The evolution of Internet begins with connecting two computers together and then moved towards creating World Wide Web by connecting large number of computers together. The mobile-Internet emerged by connecting mobile devices to the Internet. Then, peoples' identities joined the Internet via social networks. Finally, it is moving towards Internet of Things by connecting everyday objects to the Internet.

Opportunities of IoT in 3 Dimensions

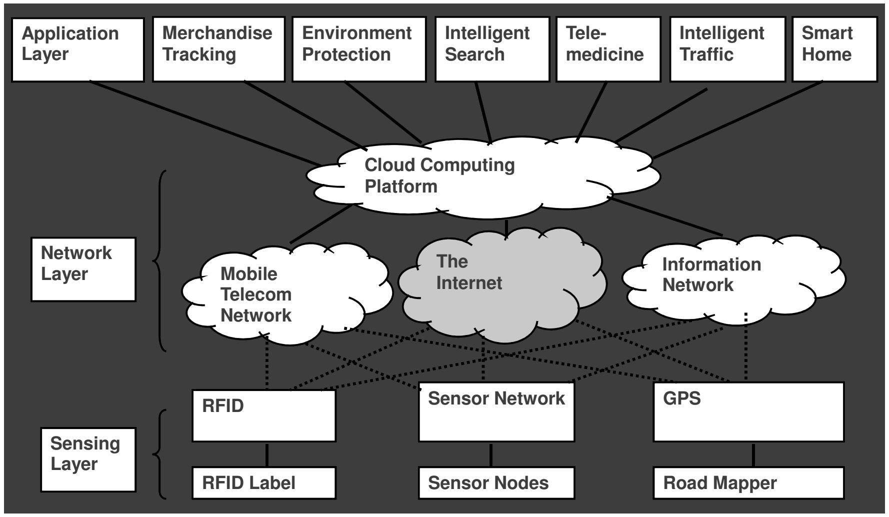


(courtesy of Wikipedia, 2010)

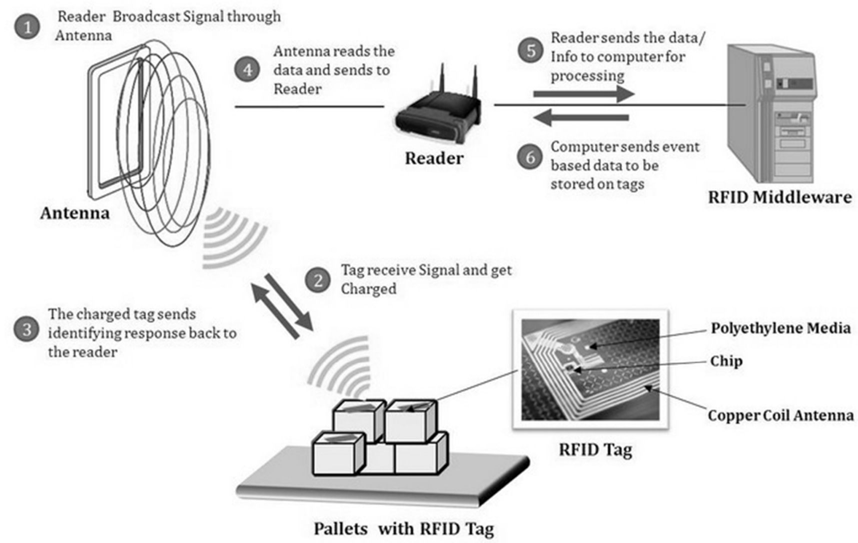
IoT Enabling Technologies



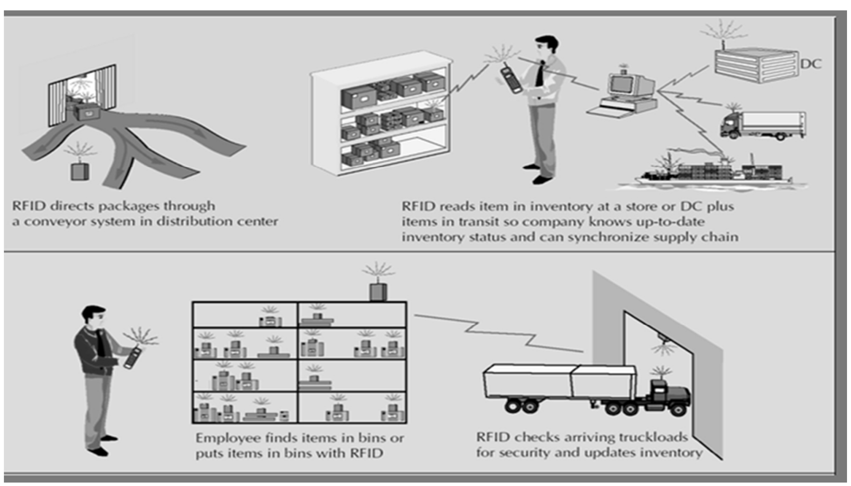
Architecture of The Internet of Things [1]

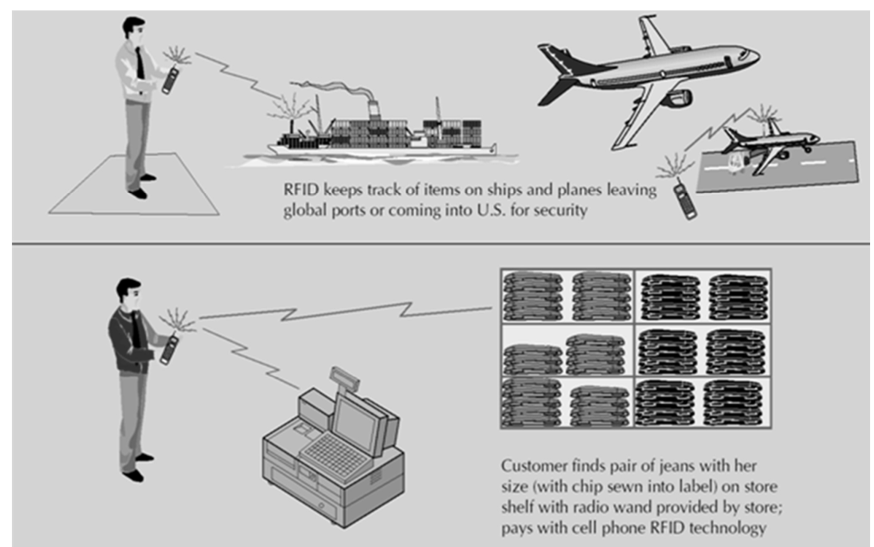


RFID Technology



RFID Merchandize Tracking in Distribution Center

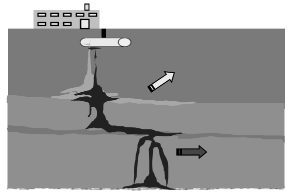




Networked Sensing Applications

Seismic Structure response

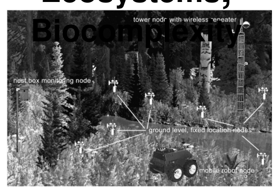
- Micro-sensors, on-board processing, wireless interfaces feasible at very small scale--can monitor phenomena up-close
- Enables spatially and temporally dense environmental monitoring
- *Embedded Networked Sensing will reveal previously unobservable phenomena*



Contaminant Transport

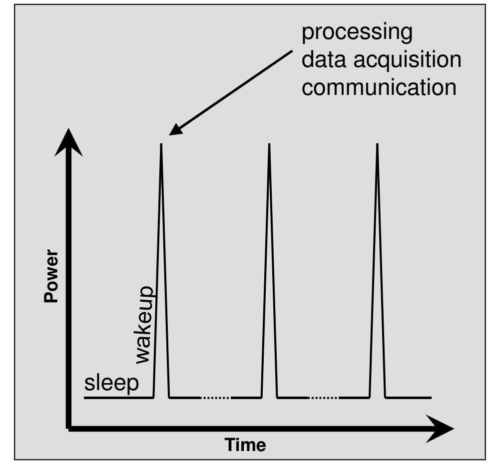
Marine Micro-organisms

Ecosystems, Biocomplexity

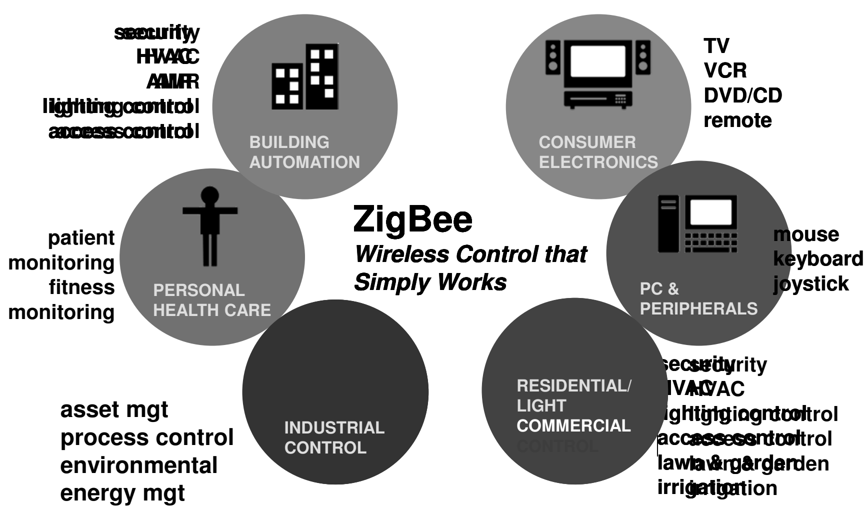


Typical WSN Application Pattern

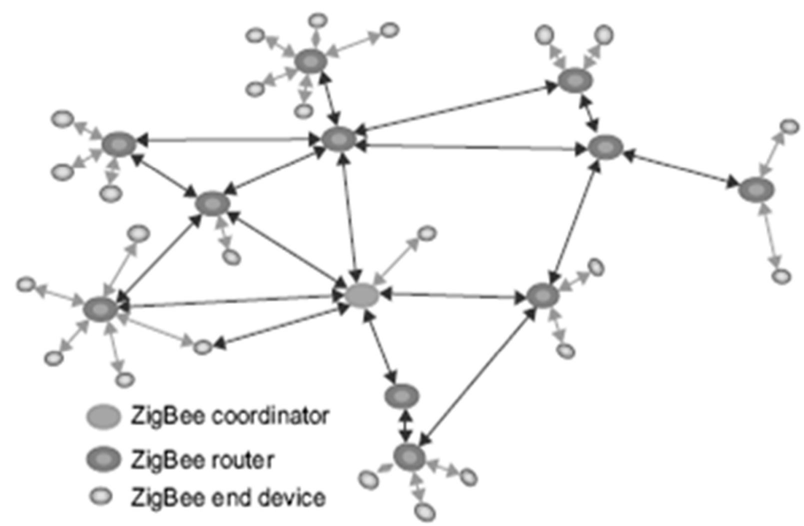
- Periodic
  - Data Collection
  - Network Maintenance
  - *Majority of operation*
- Triggered Events
  - Detection/Notification
  - *Infrequently occurs*
    - *But… must be reported quickly and reliably*
- Long Lifetime
  - Months to Years without changing batteries
  - Power management is the key to WSN success



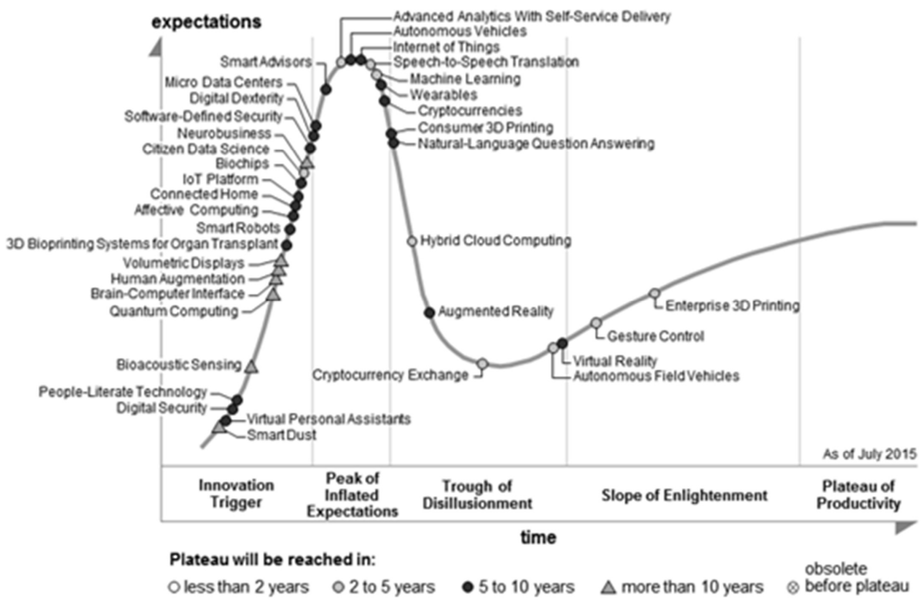
ZigBee Applications (Wireless Home-Area Networks, WHAN)



Typical Zigbee Architecture



Gartner's 2015 Hype Cycle of Emerging New Technologies:



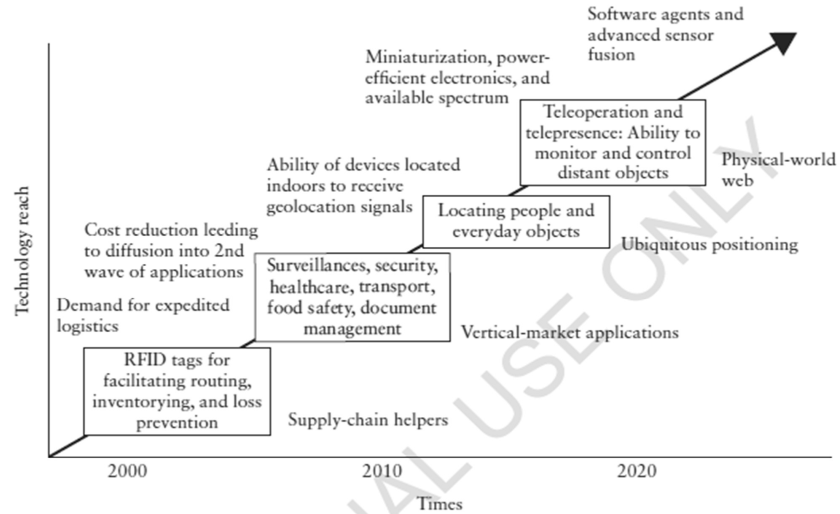


Figure 2.5
Technology road map of IoT applications. Courtesy of SRI: Consulting Business Intelligence, "Disruptive Technologies Global Trends 2025."

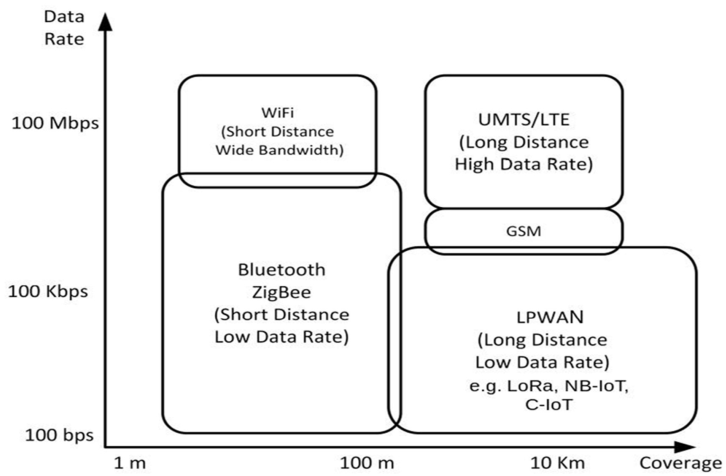
Table 4.7: IoT Wireless Communications and Networks

Network Types	Wireless WAN	WMAN	WLAN	WPAN	
Market Name Standard	GSM/GPRS CDMA/1XRTT	WiMaX 802.15.6	Wi-Fi 802.11g	ZigBee 802.15.4	Bluetooth 802.15.1
Application focus	Wide Area Voice and Data	Data, Bandwidth for WIFI AP	Web, Email, Video	Monitoring & Control	Cable Replacement
System Resources	16 MB+	8 MB+	1 MB+	4 KB – 32 KB	250 KB+
Battery Life (days)	1-7	1-7	0.5-5	100-1000+	1-7
Network Size	1	1	32	Unlimited (2^{64})	7
Bandwidth (KBs)	64-128+	75,000	54,000+	20-250	720
Range (meters)	1000KM +	100KM (LoS) 40KM (NLoS)	1 - 100	1 – 100 +	1 – 10 +
Success Metrics	Coverage, Quality	Speed, Coverage	Speed, Flexibility	Reliability, Power, Cost	Cost, Convenience

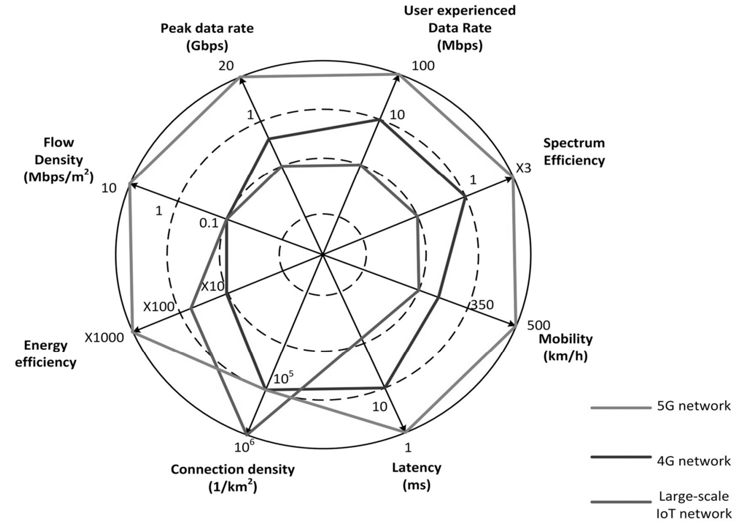
Key Applications of The IoT

Domain	Brief Descriptions	Indicative examples
Industry and Commerce and Business	Activities involving financial or commercial transactions between companies and organizations	Manufacturing, logistics, service sector, banking, financial governmental authorities, retailing, supply chains, dealers, ntermediaries, etc.
Environment Energy, and Resources	Activities regarding the protection, monitoring and development of all natural resources	Agriculture & breeding, recycling, environmental management services, energy management, smart grid projects, etc.
Smart home, city, and earth development	Utilities, appliances, health-care, community services, entertainments, tourist, weather services, tec.	Bill Gates smart home, smart cities projects in many countries, IBM smart earth project, Google map services , etc.
Transport, and Public Services	Public transportation, traffic and crisis management, logistics, parking, emergency and dister recovery, etc. s	Intelligent highways, national parks, election, crowd sources, police services, public safty, crime prevention, etc.
Community services, National Defense	Government activities/initiatives, infrastructure, military defense, battle field management, etc.	Governmental services towards citizens and society structures, e-inclusion (aging, disabled people), etc.

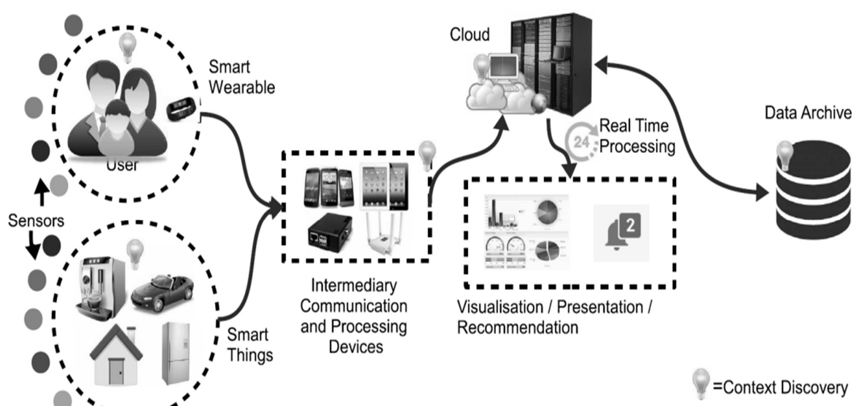
Comparing LPWAS (Low-Power Wide-Area Network) with Other Wireless Technologiesnce



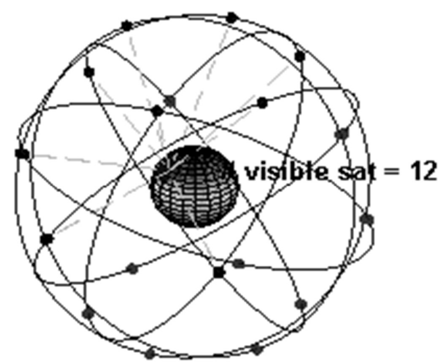
Large-Scale IoT Network Upgrading 4G/5G Mobile App Performance

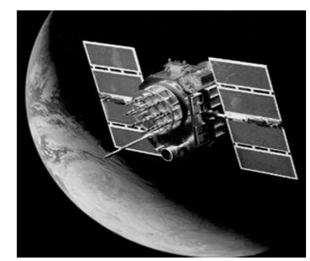


Location-Sensitive Applications of Typical IoT Processing Stages



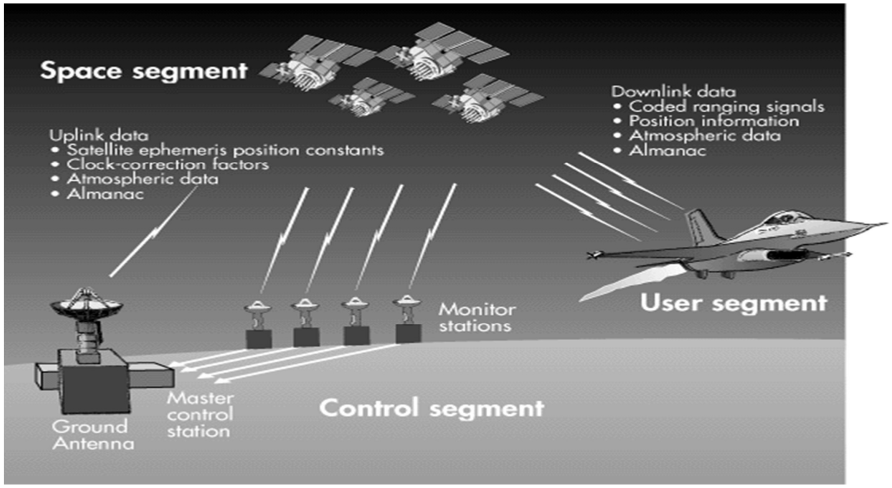
24 Satellites of GPS Deployed in Outerspace





A visual example of the GPS constellation in motion with the Earth rotating. **Notice how the number of *satellites in view* from a given point on the Earth's surface, in this example at 45°N, changes with time.**

The US GPS System over 24 Satellites for Bothe Civilean and Military Apps



GPS Operation Principle

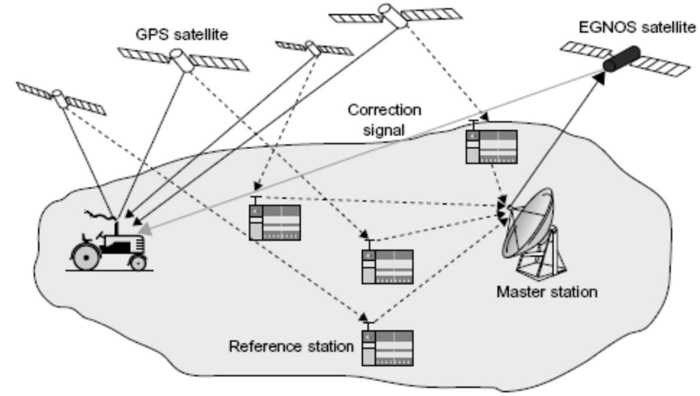
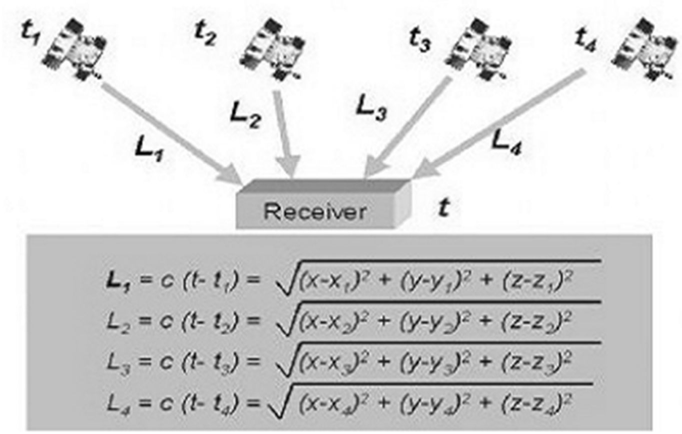


FIGURE 9.20

The Ground GPS Receiver, Which Calculates Its 3D Location from Four or More Satellites with Help from a Few Ground Reference Stations and a Master Station.



Triangulation method to calculate delayed location signals from 4 satellites.

Four Global Positioning Systems
in US, Russia, Europe and China

System	GPS	GLONASS	GALILEO	COMPASS
First Launch	22-Feb-78	12-Oct-82	28-Dec-05	13-Apr-07
FOC	17-Jul-95	18-Jan-96	2012	2013
Service	Military, Civilian	Military	Commercial, Open	Authorized, Commercial
Satellite No.	31	24	27	35
Orbital planes	6	3	3	3
Semi-major Axis [Km]	26560	25508	29601	27840
Period	11h 58m	11h 15m	14h 05m	12h 50m
Organization, Country	GPST in US	UTC in Russia	GST in EU	UTC in China

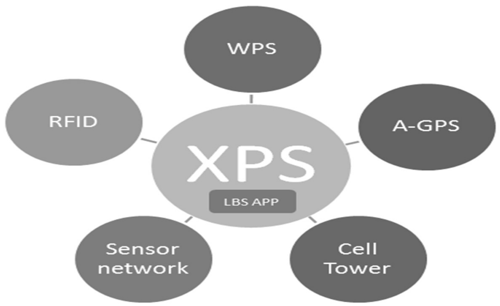
XPS: Hybrid Positioning System (Like Google Map)

WPS : Wireless Positioning System (WiFi, Cell Tower, RFID)

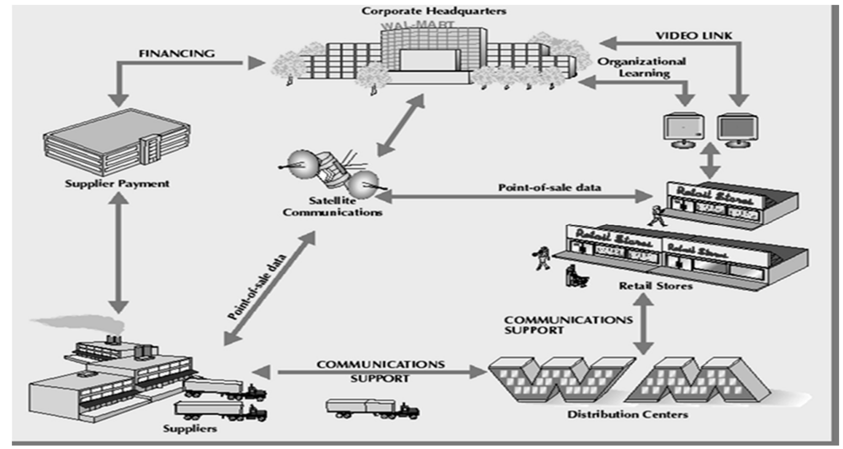
a-GPS: Assisted Global Positioning System

RFID- Radio Frequency Identification (e-labels)

LBS: Loacation-Based System (Location-Aware System)



Supply Chain Management supported by the Internet of Things. (http://www.igd.com)



Four Major IoT Components :

Wireless Sensor Network (WSN): Spatially distributed sensors to monitor physical or environmental conditions. WSNs emphasizing the information perception through all kinds of sensor nodes -- A basic scenario of the IoT.

Machine to Machine (M2M) Communication: Typically, M2M refers to   data communications without or with limited human intervention among various terminal devices such as computers, embedded processors, smart sensors/actuators and mobile devices, etc.

Four Major IoT Components :

Body-Area Network (BAN): Use of advances on lightweight, small-size, ultra-low-power, and intelligent monitoring wearable sensors, which continuously monitor human's physiological conditions for health status and motion control

Cyber Physical System (CPS): It is a system of collaborating computational elements controlling physical entities.

Body-Area Networks (BAN) for Health-Care and Other Personal Applications

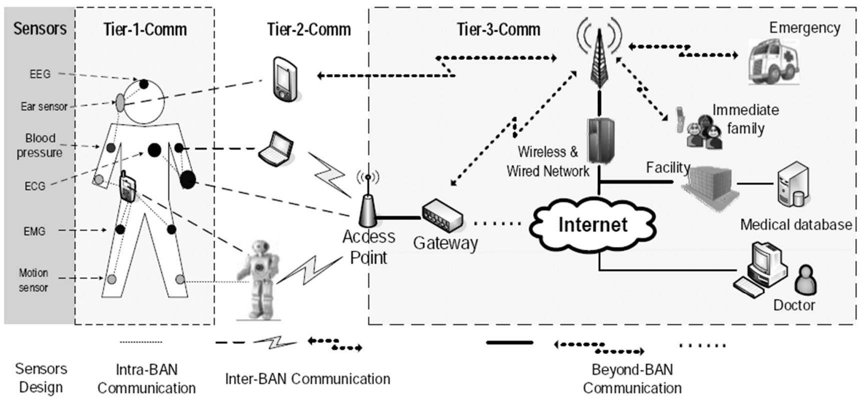
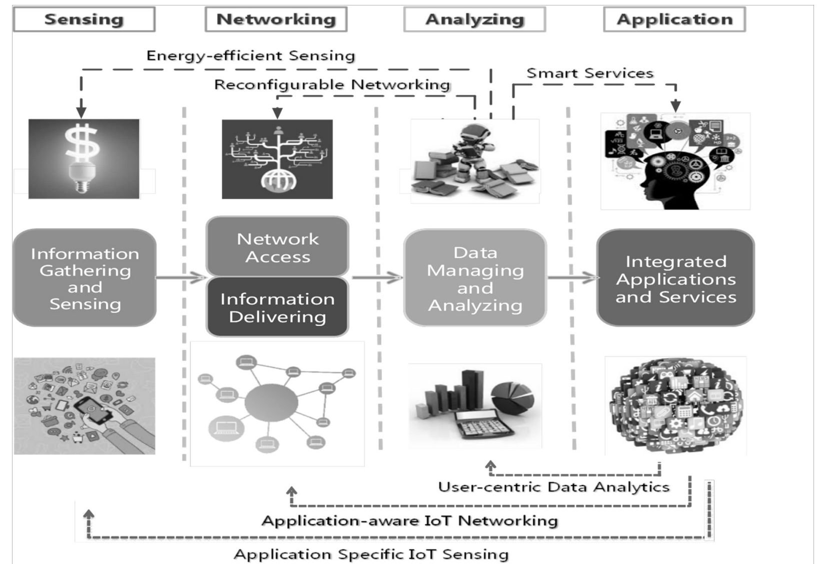


Figure 4.9 A three-tier architecture based on a BAN communications system.



Smart Interactions among IoT Applications and Sensing, Networking and Analytics

Four IoT Computing and Communication Frameworks

Table 2.7 Requirements of Four IoT Computing and Communication Frameworks

Framework	WSN	M2M	BAN	CPS
Sensing Requirement	XXXX	XX	XXX	XXX
Networking Demand	XX	XXXX	XX	XXXX
Analyzing Complexity	XX	XX	XXX	XXXX
Application Industrialization	XXXX	XXX	XX	X
Security Demand	X	XX	XXX	XXXX

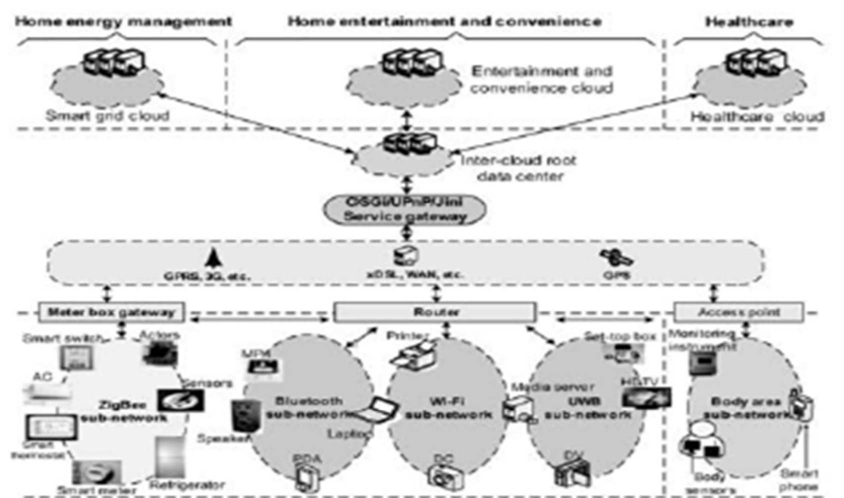


Figure 2.8
Cloud-centric IoT system for smart home development. Reprinted with permission fr
Big Data Analytics for Cloud, IoT and Cognitive Learning, Wiley, 2017.

IoT Apps Doamins and End Users

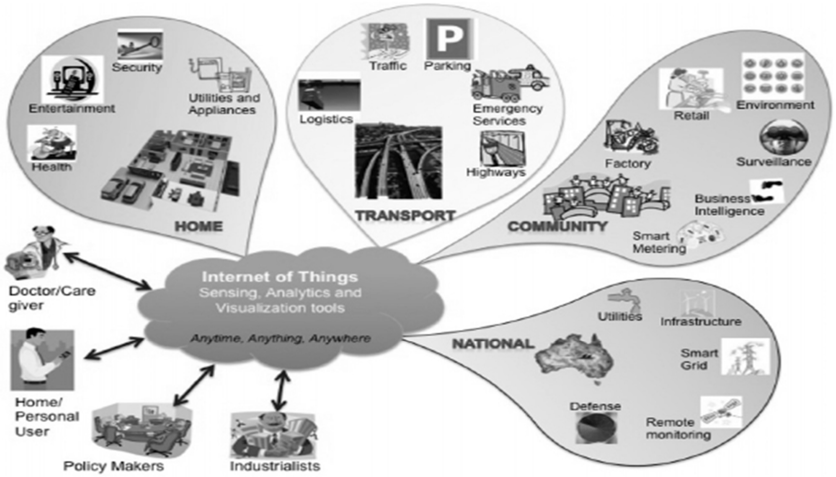


Fig. 1. Internet of Things schematic showing the end users and application areas based on data.

IoT Counts on Cloud Storage and Processing Power

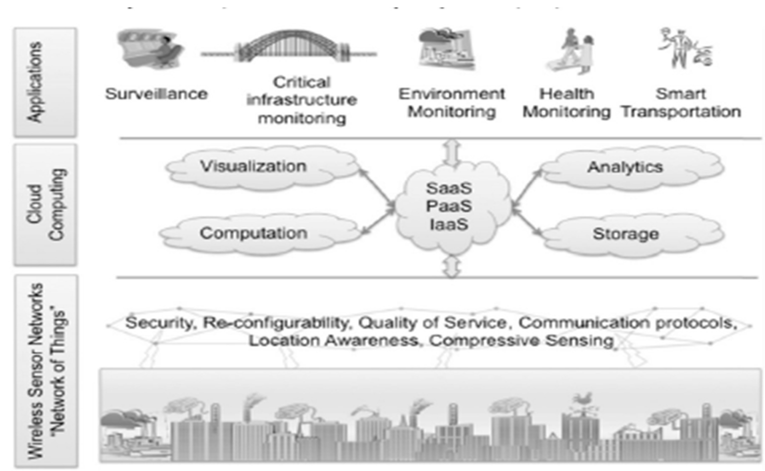


Fig. 4. Conceptual IoT framework with Cloud Computing at the center.

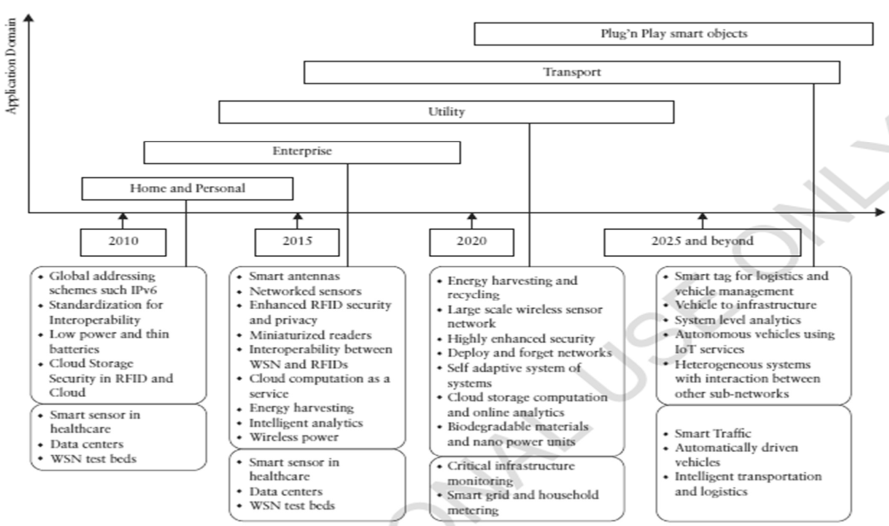


Figure 2.6
Projected upgrades in five IoT application domains from 2010 to 2025. Courtesy of J. Gubbi et al., "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions," *Future Generation Computer Systems* 29 (2013).

Cloud Support in Internet of Things and Social Network Applications

1. **Smart and pervasive cloud applications for individuals, homes, communities, companies, and governments, etc.**
2. **Coordinated calendar, itinerary, job management, events, and consumer record management (CRM) services**
3. **Coordinated word processing, on-line presentations, web-based desktops, sharing on-line documents, datasets, photos, video, and databases, content distribution, etc.**
4. **Deploy conventional cluster, grid, P2P, social networking applications in the cloud environments, more cost-effectively.**
5. **Earthbound applications that demand elasticity and parallelism to avoid large data movement and reduce the storage costs**

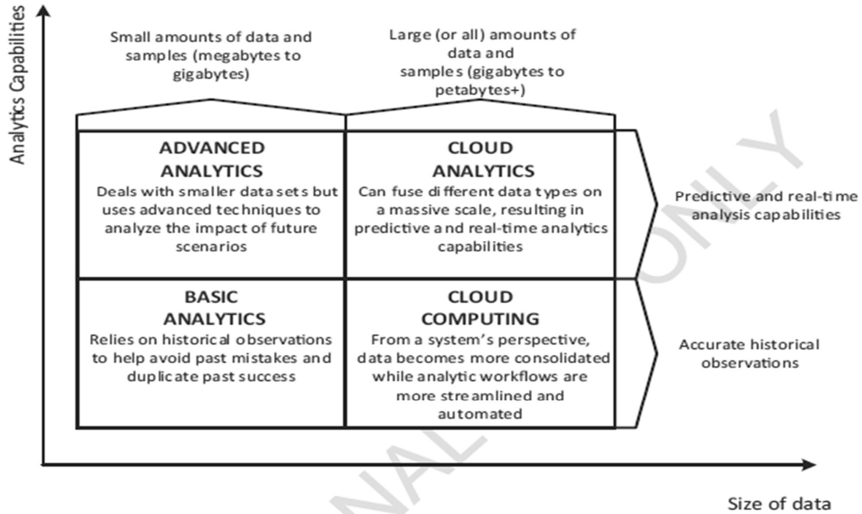


Figure 2.11
The evolution from basic analysis of small data (MB to GB) in the past to sophisticated cloud analytics over big data sets (TB ~ PB) by 2016 standard.

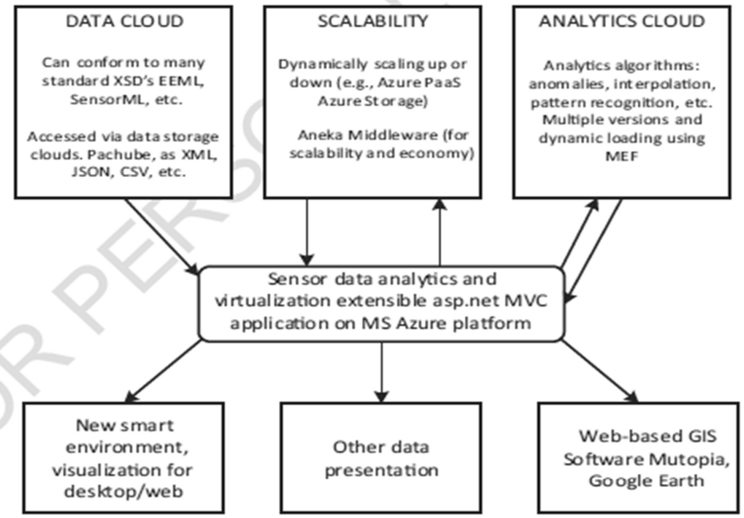


Figure 2.12
System contexts for data analytics applications on various cloud types. Courtesy of J. Gubbi et al., "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions." *Future Generation Computer Systems* 29 (2013).

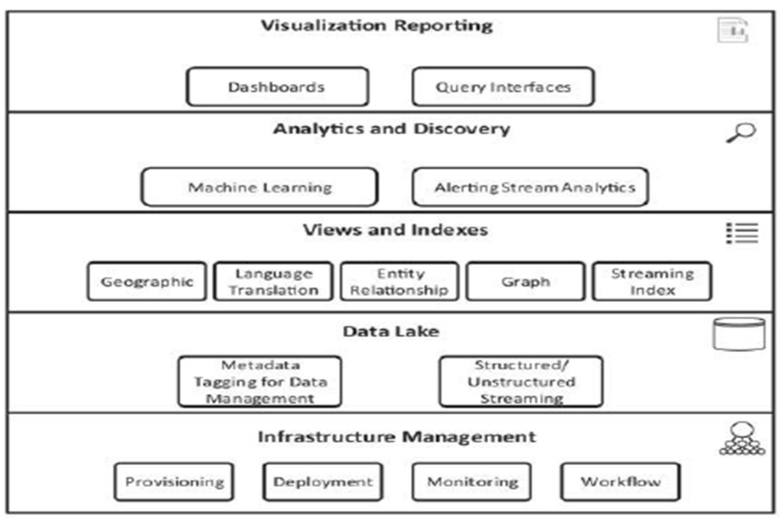


Figure 2.13
Layered development of cloud platform for big data processing and analytics applications.

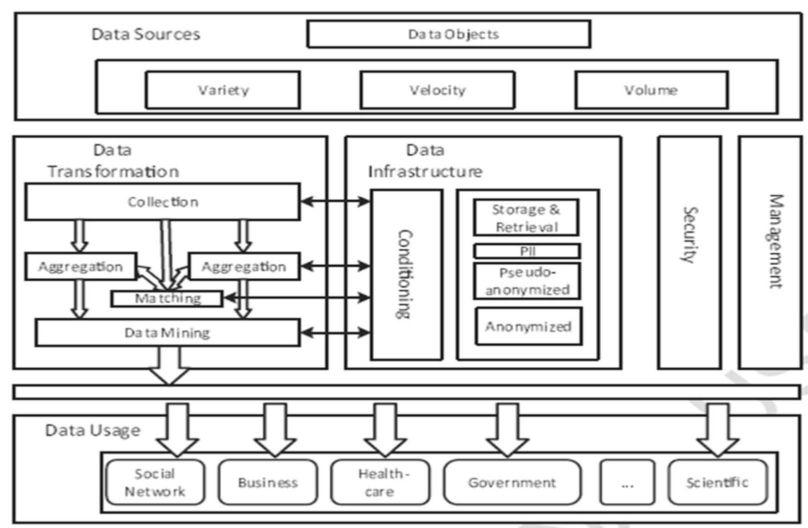


Figure 2.14
Conceptual architecture of a modern cloud system for big data computing applications.