T-110.5150 Applications and Services in the Internet

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Question 1

1.1. Give a taxonomy of peer-to-peer (P2P) networks. Compare the advantages and disadvantages of each category

According to [6], there are different taxonomies of P2P network. This section will present one way of classifications of P2P network which is based on how the data are indexed in the system. In this taxonomy, there are 4 main types of P2P network: Centralized Index, Local Index, Distributed Index and Hybrid.

Local index

In local index system, each peer has references to its own data only. There is no single central computer which knows all the data of the network. Therefore, when one node searches for a file, it sends query to nearby nodes, which might continue forwarding the query to other nodes of the network until the file is found. This kind of search is called flooding-based search. Gnutella is an example of local index P2P system.

Strengths: System is fully distributed, thus there is no need for an centralized index server. The network is also highly tolerant because there is no central bottleneck.

Weaknesses: The flooding-based search is extremely expensive in both time and network resources. Furthermore, the Query radius (Time to live) is also limited; therefore, a search might not finish in time.

Centralized Index

In centralized index system, indexes for all data are stored in one centralized index server. This server does not stores any real data but the meta-data of the clients connected to it. When one client makes a search query, the index server returns the address of the client which has the corresponding data. These two clients then establish their own connection to retrieve the data. An example for this kind of network is Napster.

Strengths: The search process is fast and efficient since the clients only need to request the index server.

Weaknesses: The index server has to process a large amount of requests. It might become a bottleneck for the whole system.

Distributed Index

In a distributed index network, references to real data are stored in several nodes instead of in a single node like in the centralized index network. A common way of achieving this is via Distributed Hash Table (DHT).

Strengths: The routing process and data query is fast. With some routing algorithms, query time can be logarithmic. This kind of network is also highly scalable.

Weaknesses: The process of maintaining mapping table is complicated. Furthermore, the system cannot adapt quickly when there are changes in the network structure.

1.2. Describe the strengths and weaknesses of P2P technology as a whole (from both technical and non-technical perspectives).

Strengths

- **Cost-effective**. There is no or less requirement for infrastructure than in the traditional client-server architecture.
- **High availability**: in most P2P systems, the content is distributed among peers. Therefore, the content is accessible most of time.
- **Highly scalable**: P2P network can handle large networks. It also adapt quickly with changing number of connection in large quantity.
- **Everybody can contribute content without cost**: data can be shared from any client. There is no need for a data storage in a centralized server.

Weaknesses

- **Security concerns**: in P2P network, since there is no centralized server which monitors and verifies the content, viruses or malwares can be easily transported to clients.
- **Legal action & legislation**: Due to uncontrollable nature, P2P systems caused a lot of concerns and disagreements from governments and organizations.

Question 2

Describe the approaches to improve the energy efficiency of mobile platforms. Explain in detail.

Modern mobile devices, including smartphones and tablets, are becoming more and more powerful. However, the battery capacity is still a bottleneck on such devices. Therefore, reducing energy consumption is important on mobile platforms. There are several approaches to encouter this problem, which can be classified into 4 categories: Hardware, Operating System, Network communication and Applications.

Hardware

Advancement in hardware can bring energy efficiency to mobile devices. An example is the invention of Intel Haswell CPU generation. It has identical CPU speed compare to 3rd gen core-i CPU but consumes much less energy.

Operating System

There are numerous researches focusing on utilizing the low-power states of mobile platform. They are mostly focus on different mechanisms to monitor and control CPU idle times during process execution [11]. Achieving this goal needs the changes in the operating system level.

Network communication

Energy consumption can be improved by optimizing network communication. The reasons are as follows. First, it has been showed that sending data in bursts is more efficient than in a continuous and slow connection. Secondly, energy wasted after the completion of a data transfer in mobile data network is significant. Therefore, changing to a better network type, such as LTE, is a good approach to solve this problem. Thirdly, there are a lot of undesired traffics in mobile devices (due to ports scan, malware, misconfiguration, etc.), which also consumes a large amount of energy. Using better platform which is more secure and transparent to end-users can help to tackle this problem.

Application

Heavy computation and fancy user interfaces are some issues on the application level with energy efficiency. For computation, thin client architecture is one of the best approaches. In thin client, computations are offloaded to cloud server, thus eliminating the need for expensive operations in the client. For user interfaces, there is always a trade-off between fancy user interfaces and energy consumption. Therefore, avoiding unnecessary application enhancement is the only way to increase energy consumption on mobile platform.

Question 3

3.1. Describe the streaming techniques to distribute content

There are a number of delivery models for distributing streaming contents, which will be described in the following.

Server

This approach is simple and widely used. Users upload their content to public providers, such as Youtube, and Google Video. Other users can use standard clients (browsers) to access the content. This approach usually comes with a limited capacity and stream quality. It is also expensive to scale.

Server grid

This approach uses Content Delivery Network to server content to the clients. It is also expensive to scale.

IP Multicast

This approach sends content to the interested users using IP Multicast technique. It is not available in large scale Internet because of both technical and non-technical issues. It is perhaps only possible in local environments.

Peercasting

In this technique, each receiver of the stream also forward content to other receivers. Therefore, in theory, it does not require centralized servers and is infinitel scalable. However, it comes with a number of challenges, such as churn (peers constantly join and leave the network), limited peer capabilities, and limited peer visibility.

Multicast tree

It is the first practical approach, in which peers form a tree topology. It works in practice, but it has a number of problems, such as large output bandwidth required, tree optimization, and tree repair due to churn.

Data-driven overlay

It is the mainstream practical approach. Chunk is streamed in small pieces which are distributed in swarm. It is the most large-scale solution. The main problem of this approach is flash crowds.

3.2. Describe the non-streaming techniques to distribute content

Web proxy caches

The web proxy caching technique stores a copy of frequently accessed objects, such as documents and images in caches which are close to users, thus serving user requests faster.

There are two types of web caches: forward or reverse proxy. The forward proxy is inside the client's internal network, while the reverse proxy is at the server side. When a client attempts to access an resource on the Internet, the request will pass through the proxy first. If the proxy has an up-to-date version of the resource, it will return the resource back to the client. Otherwise, it will forward the request to the original server. In the latter case, the proxy can store the response from the original server in its cache. There is usually limitation on the capacity of the cache, thus replacement policies (eviction strategies) need to be applied on the cache when it is full. Some example of such policies are Least Recently Used, Most Recently Used, and Least Frequently Used.

Cooperative web caches

In this technique, the cached content is splitted into multiple communicating proxies. A proxy can forward a request to other proxies to either find the requested resource or discover if the resource can be returned faster than a request to the original server [15]. This type of caching is mostly suitable to small population.

Content Delivery Network

Content delivery network (CDN) is a geographically distributed system for content delivery. There are four known types of CDN:

- **Push CDNs**: The push CDNs work similarly to a secondary server. In this type of CDN, the user or the primary server is responsible for pushing content to the CDN. Therefore, the edge servers have an up-to-date copy of resources before requests.
- **Origin Pull CDNs**: In this type of CDN, the CDN is responsible for putting files onto the CDN servers. When users ask for a specific resource, the first request will go to the original server, but subsequent requests are served from cache.
- **Application CDN**: With this type of CDN, not only the content but the whole server side applications are replicated on the CDN edge servers.
- **Peer-to-peer**: The users not only make requests for resources but also help to share and serve requests on them.

Question 4

4.1. Explain the principles of nano communications.

There are two main types of communication in the nanoscale: molecular communication and nano-electromagnetic communication.

Molecular communication

In molecular communication, transferred information is encoded in molecules, such as DNA, proteins, or peptides. This way of communication makes it feasible to create communication systems and networks using biological components and processes which can be found in nature.

Molecular transceivers are small, so they can be easily integrated in nano-devices. These transceivers are able to react to specific molecules and to release others as a response to an internal command or after an internal action [2]. Depending on the propagation way of the released molecules, which can be diffusion-based, flow-based, or walkaway-based, different channel models and communication protocol can be formed.

Nano-electromagnetic communication

Nanodevices can also interact through electromagnetic communication. In this type of communication, information is transferred in the form of electromagnetic radiation from components based on novel nanomaterials, such as graphene and its deravatives (i.e. Graphene nanoribbons, and Carbon nanotubes). The electromagnetic waves propagate in the Terahertz band via graphene-based antennas. This type of communication is fast but it suffers from path loss and molecular noise.

4.2. Describe the typical application scenarios of Internet of Nano Things.

Nanosensors are not just tiny sensors but a device that can be used to identify and measure many types of information in nano scale, such as the physical characteristics, chemical compounds, or the presence of biological agents [9]. Therefore, the Internet of Nano things can be applied in many scenarios, including: Biomedical applications, Military and defense applications, Environmental and agricultural applications, Energy efficiency applications, and cross-domain applications.

Biomedical applications: biological nanomachines (NMs) can be deployed over or even inside human body to monitor vital biological measurements, such as disease processes, in patients. These measurements provide provide near-real-time information to the healthcare provider. Such nanomachines can also form the network, known as body area nanonetworks (BAN), which is used to realize more sophisticated medical problems since the NMs can coordinate and share information through the network.

Military & defense applications: nuclear, biological and chemical defenses and damage detection systems are two examples of applications in this field [9]. These systems make use of the fact that a network of nanosensors can detect harmful chemical weapons in various scenarios, from batterfield to indoor environments, such as airport or conference room.

Environmental & agriculture applications: a network of chemical nanosensors can be used in many environmental applications, including air pollution control, water contamination control, greenhouse gasses control, and radiation control. It can also be used to detect harmful bacteria and agents in drops and livestock [4].

Energy efficiency applications: nanomaterials can be deployed to optimize the energy consumption of buildings. For example, smart windows which are built with Vanadium Dioxide (thermochromatic material) nanostructures, can be used to control the amount of light and heat to pass through them, thus saving energy consumption in the buildings.

Cross-domain applications: an application of the Internet of Nano things could expand across different domains. An example of such application is smart city which may involve smart agriculture, environment, and energy.

Question 5

5.1. Describe the indoor localization technologies, and compare their strengths and weaknesses

There are a number of indoor localization approaches available nowadays. They use different kinds of technologies: WiFi, FM signal, Radio frequency, Infrared, Bluetooth, and Ultrasound. Due to the length limit of this question, I will describe only some main technologies.

WiFi-based positioning

WiFi-based positioning is based on collecting Received Signal Strength (RSS) and the identity (e.g. SSID or BSSID) of the available access points (AP) at a number of positions, and the fingerprinting method. The accuracy of this method depends on the number of positions that are in the fingerprinting database.

The fingerprinting method consists of two phases: calibration and estimation. In the calibration phase, a database is constructed using the measurements that have been collected. The estimation phase happens when localization is performed. The measurement at the current position is collected and then compared against the database. The position is consequently estimated using the best match.

Strengths: It is convenient for users. Since most devices nowadays possess WiFi capabilities, there is no need for the users to use special devices, like tags, or transceiver. In addition, WiFi has become a standard and Wifi networks are available anywhere; therefore, a company can install a Wifi positioning system without additional hardware infrastructure.

Weaknesses: The process of collecting measurements for the fingerprinting database is complicated and time-consuming. Furthermore, different WiFi devices come with different RSS values at the same position. Therefore, they need to be calibrated individually to correctly estimate the location. Another weakness is that WiFi signal is susceptible to human presence, fading, and multipath because of its operating frequency range [7].

FM-based positioning

FM-based positioning systems operate in the same way like WiFi-based systems, but they work on FM radio signals from radio station instead. An example of such system is the one in [7]).

Strengths: FM signal can travel great distance, thus a small number of radio stations can cover a big area. The accuracy of this approach is also higher than that of the WiFi-based approach. FM stations are also more stable and degrade less over time, thus requiring less calibration [7]. Furthermore, FM signals are considered to be efficient in energy usage and are often allowed in sensitive environments [10].

Weaknesses: The devices which support FM signal are not widely available to common users nowadays.

Active Radio Frequency Identification (RFID)-based positioning

A RFID location system includes RFID scanners at different positions throughout its facility. These scanners can get information from either active or passive RFID tags. Active tags allow much wider range than passive tags (20 feets in comparison to a few inches) because they include a radio transceiver. Therefore, active tags are more common.

Active RFID tags contain unique electronic codes, which are stored in a centralized station along with the corresponding client information. The RFID scanners, which are placed at known positions, can detect the tags and tell the centralized station. Based on the location of the readers that detect the tags, the station is able to estimate the location of each client.

Strengths: The accuracy is high since the range of RFID tags is small. Moreover, it is seamless to users because of the no contact and non-line-of-sight nature of this technology [12]. It can also be used to track almost anything because we just need to attach the RFID tags to what we want to track. Therefore, it can be used in various applications, such as item tagging in retail stores, access control, and transportation.

Weakness: This approach is not convenient for the users since they need to bring a RFID tag. It is also costly to scale because a large number of RFID scanners and tags are needed. Furthermore, some RFID systems intefere with the wireless LANs (WLAN), thus decreasing the throughput of the nearby WLANs.

Infrared-based positioning

In a positioning system using Infrared (IR), such as [14], each object carries a emitter that periodically transmits unique IR beacons. IR receivers are placed at different positions throughout the facility to detect the beacons. The position of the object is estimated based on the position of the receivers that detect the beacon.

This technology has almost the same strength and weaknesses like RFID solution does because they are only different in their type of signal. However, it also has other drawbacks. First, the detection range of this technology is limited because IR cannot penetrate through opaque materials, such as walls and ceilings. It also performs poorly if there is direct sunlight in the environment [3].

5.2. Describe the outdoor localisation technologies, and compare their strengths and weaknesses

GPS (Global Positioning System) and cellular-based are two widely used systems for outdoor localization. Besides, some indoor localization technologies can also be applied to outdoor system, such as Active RFID [8]. In this section, the GPS and cellular-based technologies will be presented.

GPS

GPS is a positioning system developed by the United States Department of Defence. It is based on the network of satellites to provide GPS receivers their current location, time, and velocity. Each satellite continually transmits messages, and the receivers collect these messages and estimate their location by using time-of-arrival (TOA) information and triangulation method. The location can be determined only if there is clear line-of-sight to four or more GPS satellites. According to [1], an accuracy of 3.5 meter can be provided by GPS.

Strengths: It works anywhere on the earth and there is no charge to use the signal. Furthermore, the system is self-calibrating, so no pre-configuration is needed. Beside providing location, it can also provide bearings and direction information.

Weaknesses: The GPS signal cannot pass solid objects, thus it is unable to work in such environments like water, tunnels, underground. It is also affected by large buildings, so it does not work well in big cities where there are lots of skyscrapers. It is also power-consuming

Cellular-based positioning

This approach uses the existed cellular networks, such as GSM, and CDMA, to determines the position of a mobile station (MS). The signal transmitted from the MS is measured at the Base Stations (BSs) and then sent to a central site to estimate the location of the MS [13]. This technology utilizes different measurements to estimate the location, such as angle-of-arrival, time-of-arrival, and received signal strength. The accuracy of this technology is 50 meter at best [5].

Strengths: It is mobile phones widespread. It can work indoor and in dense areas. It also comes with relatively low power-consumption (in compared with GPS). Moreover, the MS does not involve in the location-finding process, thus no modification is needed on the existing mobile devices to use the service.

Weaknesses: It provides low accuracy. The accuracy also depends on the cell density, thus it provides best accuracy in urban areas and worst in rural areas [5]. The service is also not available where there is no cellular network. Furthermore, this is a network provider-dependent service, thus it is charged by the service providers.

Question 6

Design a conceptual system that includes the technologies you have learnt from this course.

The system is: **Smart house**. It is based on one of my projects during bachelor study. The system uses the following technologies to provide a better environment for its users: mobile sensing, indoor localization, video streaming, and Internet of Things.

6.1. Overview

The system has the following functionalities:

- **Real-time monitoring** of what is happening in the house using video streaming. Multiple cameras are placed at known places inside the house, which transmit video streaming to the users' mobile devices.

- **Automatically adjusting household appliances** based on the users' position. For example, if the system detects that there is a user arriving in the kitchen, it might turn on the light in the kitchen. This feature not only brings conveniences to the users, but it also helps to optimize the energy consumption since the system can automatically turn off unnecessary devices when there is no people in a room.

  The position of the users is determined by multiple methods. A network of Passive-infrared sensors (PIRs) on the ceiling can detect if there is any user approaching a location. Other type of sensors can be attached to specific appliances, such as couches or beds, to detect whether there is any user on them.

- **Burglar detection**. The system can be configured to detect burglar at sensitive time, such as at night, or when the users are on vacation, by using the PIR positioning mechanism. If burglar is detected, the system can notify the users through their mobile devices or alarm.

- **Health-care monitoring** using mobile sensing. The sensors of the users' mobile phone can be used to detect if there is any accident happening to them. For example, the system can detect an user falling down the stairs if there is sudden change in the mobile sensors' values.

6.2. System Architecture

The system consists of two sub-systems (Figure 1). The first one is a center server with five modules: Appliances module, Positioning module, Streaming module, Security module and User devices module. It runs in a local computer inside the house. The modules connect to the center server through the local LAN. The second sub-system operate on the users' mobile devices. It consists of the health-care application and the monitoring application.

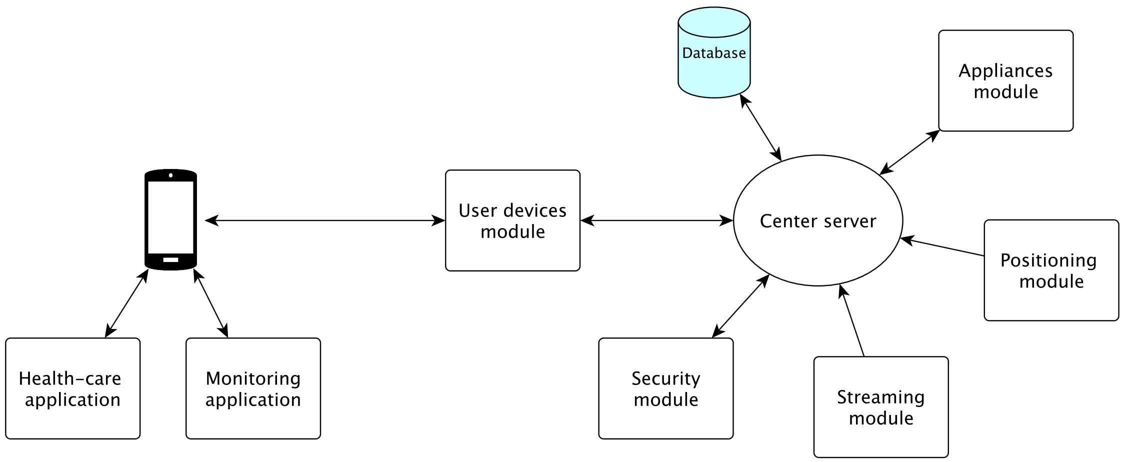

Figure 1: System Architecture

6.3. Center server

Each module in the center server provide different functionalities. Their functionalities are as follows:

- **Appliances module**: monitors the status of household appliances in the house. It is also able to send command to each device to change the device's status.
- **Positioning module**: detects the current location of the users using the network of PIR sensors and sensors on specific appliances. It updates the location of the users to the center server.
- **Streaming module**: collects data from the cameras inside the house and sends it back to the center server. The center server will store it in the database and stream it to user devices on requests.
- **Security module**: allows users to configure the places and the time in which they want to turn the security system on. This module relies on the position information that the center server collects from the positioning module to detect burglar. If burglar is detected, it either turns on the alarm or notifies the users through the User device module.
- **User devices modules**: sends/receives data from user devices.

6.4. Mobile applications

There are two applications available on mobile devices to support the system: health-care application and monitoring application:

- **The health-care application**: executes background services which continually collect the sensors information of the device. It processes the information to detect accidents happening to the user.
- **The monitoring application**: queries video data from the center server and displays it to the user.

References

[1] Gps accuracy. http://www.gps.gov/systems/gps/performance/accuracy/.

[2] Ian F Akyildiz and Josep Miquel Jornet. Electromagnetic wireless nanosensor networks. *Nano Communication Networks*, 1(1):3–19, 2010.

[3] Paramvir Bahl and Venkata N Padmanabhan. Radar: An in-building rf-based user location and tracking system. In *INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*, volume 2, pages 775–784. Ieee, 2000.

[4] Sasitharan Balasubramaniam and Jussi Kangasharju. Realizing the internet of nano things: challenges, solutions, and applications. *Computer*, 46(2):62–68, 2013.

[5] Robert P Biuk-Aghai. Gsm-based provider-independent positioning method. *Location Asia*, 2007.

[6] G Camarillo. Iab," peer-to-peer (p2p) architecture: Definition, taxonomies, examples. Technical report, and Applicability", RFC 5694, 2009.

[7] Yin Chen, Dimitrios Lymberopoulos, Jie Liu, and Bodhi Priyantha. Fm-based indoor localization. In *Proceedings of the 10th international conference on Mobile systems, applications, and services*, pages 169–182. ACM, 2012.

[8] Xin Huang, Ramakrishna Janaswamy, and Aura Ganz. Scout: Outdoor localization using active rfid technology. In *Broadband Communications, Networks and Systems, 2006. BROADNETS 2006. 3rd International Conference on*, pages 1–10. IEEE, 2006.

[9] Broadband Wireless Networking Lab. GRANET: Graphene-enabled nanonetworks in the terahertz band. http://www.ece.gatech.edu/research/labs/bwn/projects/granet/projectdescription.html.

[10] Aleksandar Matic, Andrei Papliatseyeu, Venet Osmani, and Oscar Mayora-Ibarra. Tuning to your position: FM radio based indoor localization with spontaneous recalibration. In *Pervasive Computing and Communications (PerCom), 2010 IEEE International Conference on*, pages 153–161. IEEE, 2010.

[11] Alexander W Min, Ren Wang, James Tsai, Mesut A Ergin, and Tsung-Yuan Charlie Tai. Improving energy efficiency for mobile platforms by exploiting low-power sleep states. In *Proceedings of the 9th conference on Computing Frontiers*, pages 133–142. ACM, 2012.

[12] Lionel M Ni, Yunhao Liu, Yiu Cho Lau, and Abhishek P Patil. Landmarc: indoor location sensing using active rfid. *Wireless networks*, 10(6):701–710, 2004.

[13] Ali H Sayed, Alireza Tarighat, and Nima Khajehnouri. Network-based wireless location: challenges faced in developing techniques for accurate wireless location information. *Signal Processing Magazine, IEEE*, 22(4):24–40, 2005.

[14] Roy Want, Andy Hopper, Veronica Falcao, and Jonathan Gibbons. The active badge location system. *ACM Transactions on Information Systems (TOIS)*, 10(1):91–102, 1992.

[15] Alec Wolman, M Voelker, Nitin Sharma, Neal Cardwell, Anna Karlin, and Henry M Levy. On the scale and performance of cooperative web proxy caching. In *ACM SIGOPS Operating Systems Review*, volume 33, pages 16–31. ACM, 1999.