# Heterogeneous Networks

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Communication technologies have drastically increased the number of wireless networks. Heterogeneous networks have now become an indispensable fact while designing the new networks and the way the data packet moves from device to device opens new challenges for transmitting the packet speedily, with maximum throughput and by consuming only confined energy.

scrumptious heterogeneous network IoT device

## 1. Introduction

The deployment process of traditional wireless cellular networks is inherited from past scenarios and requires time-to-time upgradation. The state of the art cellular systems are basically encompassed in base stations and user terminals adopting the same standards as followed by the cellular system in other regions. Currently, wireless networks are keystones, with several diverse application fields, such as wireless sensor networks, cloud facilities, cyber physical systems [1], infrastructures protection, and command control, with several other likely examples. The wireless workstation networking has taken the place of former customary technologies to provide better services with configurability, flexibility, and interoperability [2].

Contemporary network technologies are comprised of software and hardware components. The accessibility of faster and reliable hardware is altering the equilibrium between software and hardware with generating changes in the network of structured devices. Currently, several software-built nodes based on the Python language coexist with hardware-built nodes with the provision of many analogous functions in conjunction with different computing tools [3].

Heterogeneous networks [4] contain numerous existing radio access network (RAN) technologies, such as WiMAX, Wi-Fi, EUTRAN, etc., and have various architectures, different transmission mechanisms, and base stations with a volatile performance range. Configuration networks are used to improve the user experience and reduce RAN and core network (CN) bottlenecks. HetNet [5] can also help to route and manage intelligent IP traffic, and implement efficient load balancing and resource allocation. This is the aggregation of heterogeneous network radio resources and the traffic between selective or packet-switched or circuit-switched HetNet. 3GWLAN has been considered beyond other inter-technology options. Heterogeneous networks include interconnected nodes and different types of links. Such interconnected structures contain a wealth of information that can be used to mutually strengthen nodes and links and transfer knowledge from one type to another.

The heterogeneous wireless sensor network demands an abundant network resource. It attempts to deploy a replication connectivity mechanism in a fast mobile architecture. The real measurement output exhibits that the replication connection mechanism drastically reduces network uncertainty, controls the packet loss ratio, and proactively improves the network throughput. A small network fidelity significantly influences the outcomes of assessments when the network complexity is not inconsequential, so the obtainability of integrated simulation-centered tools to maintain the whole network course is an actual need to evade the underestimation and equivocation of network glitches [6].

Modular simulation is very useful in building an articulate network model with varying levels of applications. The accessibility of modular, programmable, extensible, open-source, community-driven, and community-supported simulation frameworks produces simulation events with desirable outcomes even in a heterogeneous network system using varying simulated nodes [7].

## 1.1. Smart Homes

Smart homes are getting popular due to two factors. First, sensing and actuation techniques as well as wireless sensor networks, have dramatically advanced. Second, nowadays, individuals rely on technology to answer their worries about their quality of life and home security. Intelligent and automated services are provided via a range of IoT-based sensors in smart homes, which help individuals who forget to automate daily duties and maintain routines and can save energy by automatically shutting off lights and electrical gadgets. Motion sensors are employed for this purpose and security can also be achieved. Sensors collect data from the environment by conserving energy (light, temperature, humidity, gas, fire events).

The data from the heterogeneous sensor is given to the context aggregator, which then transmits it to the context recognition service engine. This engine chooses services depending on their context. When the humidity rises, for example, an application can automatically switch on the air conditioner. If there is a gas leak, you can also switch off all of the lights. Smart home applications are highly beneficial to the elderly and the disabled. Health can be monitored and professionals can be notified immediately in the event of an emergency. The floor is outfitted with pressure sensors, which aid in tracking a person’s activity in a smart home and detecting falls. CCTV cameras may be used in smart homes to record interesting occurrences. There are countless challenges and questions about smart home applications [8]. Security and privacy are of paramount importance, as all data about what is happening at home is recorded [9]. An intruder can attack the system and cause it to behave maliciously if its security and dependability are not ensured. When such abnormalities are noticed, smart home systems are meant to warn the owner.

In continuation to smart homes, there are IoT-based applications that govern with smart homes. The role of the most relevant applications to the proposed systems are discussed as follows.

### 1.1.1. IoT-Based Transport

Sensors and cognitive information processing systems can be used by IoT-based transportation apps to govern everyday traffic in the city. The primary aims of intelligent traffic systems are to reduce traffic congestion, make parking easier and stress-free, appropriately route traffic, and eliminate accidents by identifying intoxicated drivers. GPS sensors for position information, accelerometers for speed, gyroscopes for direction, RFID for vehicle identification, and infrared for counting passengers and cars are examples of IoT devices with sensor technologies for these sorts of applications, as well as sensors and cameras for documenting traffic and vehicle movements.

### 1.1.2. IoT-Based Water Systems

The current level of water shortages in most regions of the world urges critics to effectively manage the water supplies. As a result, most cities are opting for smart solutions that include the installation of a large number of meters on water supply pipes and storm drains. Smart water meters come in a variety of styles. These meters may be used to determine the amount of water entry and outflow as well as potential leaks. Water metering systems based on IoT are also employed in combination with data from meteorological satellites and river water sensors. They can also assist people in forecasting flooding.

### 1.1.3. IoT-Based Social Meetings

“Opportunistic IoT” [10] refers to information exchange between opportunistic devices (devices that seek communication with other devices) depending on mobility and availability of contacts in the neighborhood. Personal gadgets with sensing and short-range communication capabilities include tablets, wearables, and mobile phones. When there is a shared goal, people may find and interact with one another.

### 1.1.4. IoT-Based Supply Chain Management

IoT seeks to simplify the actual processes of business and information systems [11]. One can easily trace items in a supply chain from the point of manufacturing to the point of final distribution by using sensor technologies, such as RFID and NFC. Real-time data is recorded and processed for future reference. RFID tags connected to cargo can also record information regarding product quality and ease of use.

The proposed mechanism (SDS) achieves the required goals in five steps:

- Step 1: The service is separated into patterns and the attributes of each pattern are examined before using the utility function to determine the utility value for each network feature.

- Step 2: Network attribute weights are calculated using the link selection attribute (LSA). Based on this, signal inference is completed.

- Step 3: The network attribute score is calculated using the network attribute utility and weights.

- Step 4: Network settings for different scenarios are calculated using the LSA.

- Step 5: Based on the evaluation of network attributes, unpleasant networks are prioritized. This allows the user to select the network with the highest score.

## 2. Advantage of Heterogeneous Network

Traditional network resource selection approach usually chooses the network that is the best performer among all available networks. However, with diverse services, each service demands rigid features. Furthermore, various users have diverse preferences. As a result, the goal of the study introduced was to create an access selection algorithm that takes network, service, and user demographics into consideration.

Considering the low-speed moving environment, Fung po et al. [12] investigated the performance of high-speed packet access (HSPA). Not only static scenarios were taken into account, but many mobile scenarios, including subways, trains, and city buses were also considered. However, limiting the deployment of commercial networks, it analyzed only 3G networks, and all measurements primarily looked at network and transport layer parameters. Therefore, the network access layer has great priority but SNR was fully ignored during the entire transmission.

Similarly, another work from Mahfuzur [13] developed a content-centric networking (CCN) mechanism in the 4G/5G network, where various heterogeneous networks are converged. They also offered a unique mobility management method to enable content and network variety by using the mobile network's rich computing resources. Rather than establishing a communication link to the information source, they promised to enable more efficient, quicker, and secure content delivery. Furthermore, they examined existing mobility options and assessed the efficacy of a seamless content delivery mechanism in terms of content transfer time, throughput, and the data transmission success ratio. Their suggested solution uses name-based routing rather than content or device addresses. For content transfer, this system primarily employs two basic messages: the Interest packet and the Data packet. The Interest packet provides a request for a requested material, which includes information such as content name, content type, and content version. The Data packet comprises the original data as well as the content name, security information, and numerous additional properties, such as hop distance and content source description. However, they disregarded some of the issues, such as excessive energy usage and data packet delay rationing, which significantly reduce network longevity.

Qin et al. [14] proposed the reactive DSR source routing protocol for cognitive radio ad hoc networks to send IoT data from the IoT gateway to non-constrained networks inside the cognitive radio ad hoc networks. DSR, in particular, falls to the reactive routing protocol group since it may find routes from source to destination only when requested and needed. DSR is a source-routing system that allows for on-demand routing. DSR broadcasts routes to its neighbors but does not overload them with data. It only follows routes by calculating total distance or counting the number of nodes between the source and destination nodes. Nodes in the DSR mechanism keep route cache information that contains the path sequence from the source. Route maintenance and route discovery are the two processes used in DSR.

The researchers [15] claimed to improve end-to-end throughput while minimizing the latency. The gateway distributed routers also act as IoT gateway nodes, gathering and encapsulating the data into the distributed cognitive radio ad hoc network. For the IoT network to be simulated in the Cooja simulator, an assumption was made to get IoT data from the LLN node to the LNN gateway node (LBR), which also functions as a cognitive source node. When a packet reaches the CR source node, it is wrapped in IP-in-IP and delivered via the cognitive radio network simulator. Channel route identification and restoration delays via local or global channel route recovery approaches have an impact on the end-to-end cumulative network throughput inside CRAHNs. As a result, the chance of PU spectrum handoff is higher than in the absence of active PU transmitters. As a consequence, the performance of source routing with various PU transmitter nodes was being assessed in order to compute the aggregate network throughput of IoT data inside the ad hoc network. The performance of the cognitive source routing protocol was compared to the existing hybrid cognitive AODV routing protocols, licensed control channel-based AODV routing protocols, unlicensed AODV-based routing protocols, and traditional IEEE 802.11 DCF-based routing techniques. Overall, this method is only suitable for sparse networks and is impractical for dense networks; no alternate measure for dense settings was provided.

Z. Yang et al. [16] employed a directional antenna to enhance the amount of concurrent noninterfering broadcasts within the cognitive radio network. This raises the possible end-to-end throughput in multihop communication while simultaneously lowering node power consumption. In other words, by minimizing interference with directional antennas, directional cognitive control and IoT application transmission would help in obtaining greater end-to-end throughput.

Ashraf et al. [17] suggested a lower power listening (LPL) technique to monitor malfunctioning nodes and energy waste in a wireless network using ContikiMAC Cooja. In both the centralized and distributed models, energy usage is lowered. By presenting a stochastic model for wireless sensor networks, the researchers calculated energy consumption with end-to-end latency. The suggested model, however, incorporates cylindrical propagation but lacks common spherical propagation.

## 2.1. Heterogeneous Network

It has been noted that network performance is poor in high-speed mobile scenarios, unable to fulfil user requests for network resource access. The elements influencing user network performance are examined layer by layer, and the benefits of heterogeneous networks are analyzed.

### 2.1.1. Transport Layer

Each user is familiar with the shifting patterns of TCP throughput at various speeds. In every case, the performance of TCP throughput [18] appears to be the weakest, even the average of TCP throughput is the lowest, and the volatility of TCP throughput is the most dramatic. Given the statistics from the cumulative distribution function (CDF) [19], it is challenging to meet user demand for network resource access over a single wireless network. Taking use of diverse networks may be able to meet the user’s need for network access.

### 2.1.2. Network Layer

It was determined from the data travelling throughout the transport layer that the network performance of a single wireless network is poor. However, with heterogeneous networks, the overall network performance has a lot of opportunity for improvement. The benefits of heterogeneous networks with a network layer have been studied because when speed of the movement grows, the packets take longer to transport and are even lost. This might mean trouble for applications that are extremely sensitive to packet delays, such as real-time gaming. Using diverse networks may help to decrease transmission delays [20].

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