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5G VS 6G

WIRELESS TECHNOLOGY

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Abstract:

5G wireless communications technology is being launched, with many smart applications being integrated. However, 5G specifications meagre the requirements of new emerging technologies forcefully. These include data rate, capacity, latency, reliability, resources sharing, and energy/bit. To meet these challenging demands, research is focusing on 6G wireless communications enabling different technologies and emerging new applications. In this paper, the latest research work on 6G technologies and applications is summarized, and the associated research challenges are discussed. Index Terms—5G, 6G wireless communication, requirements, capacity, data rate, applications, challenges

INTRODUCTION:

Almost every ten years, a new communication system has been introduced, improving the QoS, providing new features and introducing new technologies. Although 5G is not officially launched yet, researchers have turned their attention to 6G communication system. The reason is that 5G provides a high standard infrastructure enabling a variety of technologies such as; self-driving cars, AI, mobile broadband communication, IoT and smart cities. However, the usage of smart devices is increasingly growing each year and the data traffic usage will be exponentially increasing as in Fig. 1, which puts constraints on the 5G communication network. These constraints open the door for a new communication system providing more capacity, extremely low latency, high data transmission, secure error-free communication and full wireless coverage. Table I compares the main specifications and technologies in both 5G and 6G. 6G will be able to connect everything, integrate different

technologies and applications, support holographic, haptic, space and underwater communications and it will also support the Internet of everything, Internet of Nano-Things and Internet of Bodies In this paper, some emerging technologies and applications introduced and developed by the 6G communication technology are presented in section II and the main challenges facing the achievement of the 6G goals are addressed in section III.

II. EMERGING TECHNOLOGIES AND APPLICATIONS:

Every communication system opens the door to new features and applications. 5G was the first generation to introduce AI, automation and smart cities. However, these technologies were partially integrated. 6G is introducing more technologies and applications providing higher data rates, high reliability, low latency and secure efficient transmission main applications, trends and technologies introduced in 6G. In this section, some of these technologies and applications 6G are discussed.

5G use cases and some supporting technologies

As early as 2012 there was buzz around the development of 5G with plans of it vastly surpassing 4G LTE speeds and coverage. Serving any and all applications by smartly leveraging multiple radio access technologies (multi-RAT) to better serve customers. As of 2020, there were 26 billion internet-connected devices globally, this is anticipated to increase to almost 40 billion by 2025 and nearly 50 billion by 2030—the year that 6G is expected to begin filling market demands. With the number of connected devices and bandwidth-hungry wireless applications, 5G would likely not be able to meet the speed and capacity requirements to support the number of connected devices. However, similar to how 5G is built upon the 4G infrastructure with additional components, 6G is expected to rely on the established 5G network.

As stated earlier, the 5G vision has been mainly focused on serving three applications: eMBB, uRLLC, and mMTC. These three applications however, require focused network planning around optimizing throughput, latency, and coverage respectively. The eMBB application is particularly challenging in dense urban environments where there is expected to be a massive installation of outdoor small cells as well as an extensive underground fiber optic network to support the traffic and throughput demands from the urban center. Because of this, there has been a major effort around realizing millimeter-wave (mmW) communications technology

for mobile networks—a spectrum space that was traditionally exclusively utilized for military and science purposes for radar and imaging.

What is 6G expected to support?

The applications have a natural progression to more a ubiquitous virtual experience with AR/VR applications, tactile internet along with intensive predictive analysis/modeling via the proliferation of artificial intelligence (AI) processing within said devices. These push current technologies to the next level. The mixed reality (MR) experience uses 3D objects and AI to provide a seamless, immersive experience with a high integrity 6G connection.

An example of this would be holographic communications where conventional video conferences are augmented with a realistic projection for a three-dimensional image. The concept of connected robots and autonomous systems to provide basic services such as mail/package delivery also requires a high-fidelity wireless connection to enable the proper feedback necessary to control the destinations of such equipment.

Other future wireless applications include a brain-computer interface (BCI) where appliances can be controlled via a communication path between the user's brain and the device's RF front-end. This can be extended to the medical field with medical wearables tracking/monitoring a patient's health while they are in hospice. Entirely automated industrial facilities with intensive computing will require a reliable connection to the cloud in order to perform the complex data analytics necessary for remote control and predictive analysis

Facts About 5G vs. 6G

5G and 6G exploded into the tech scene at about the same time. Just as 5G rolls out commercially, 6G research and development (R&D) projects have launched. That may lead to some confusion about the difference between the two. Here are five things to know.

5G Makes the Internet of Things Possible. 6G Speeds It Up

Part of the reason 5G is so anticipated lies in the expectation that it will finally make the Internet of Things a practical everyday reality. The frequencies used by 4G are too narrow and too crowded to transmit data at the speeds that smart devices need to function optimally. That's why they haven't gained widespread traction. That's going to change with 5G, and likely again with 6G.

5G Will Not Replace 4G. 6G Will Not Replace 5G

While 4G was 3G but faster, 5G and 6G represent different iterations of wireless connectivity. Many predictions expect 6G will be reserved for business, military, and industrial purposes with some consumer uses such as immersive entertainment. It won't be practical to have every device streaming with 6G – but other advances may change that

Both Generations Have Very Low Latency

Latency refers to the time it takes for a packet of information to transmit over a frequency. 4G latency is about 50 milliseconds. In 5G, that drops to 5 milliseconds – about 10 times lower. 6G latency is estimated at 1 millisecond, a latency five times lower than that of 5G. That almost instantaneous speed will help make massive data transmissions possible.\

Exisiting Technology

Which technique is used in 5G?

5G is based on OFDM (Orthogonal frequency-division multiplexing), a method of modulating a digital signal across several different channels to reduce interference. 5G uses 5G NR air interface alongside OFDM principles. 5G also uses wider bandwidth technologies such as sub-6 GHz and mm Wave.

Does 6G technology exist?

Technically, 6G doesn't exist yet. But theoretically speaking, it could end up being a lot of things, building on current network and technology trends to help make a completely new type of internet.

Differences between 5G and 6G network:

- **Use of different spectrum:**

  5G and 6G use wireless spectrum of higher range for data transmission faster than 4G, 3G, and 2G networks. However, when comparing 5G vs 6G, the former one is allocated for low band and high band frequencies – sub-6 GHz (Gigahertz) and above 24.25 GHz respectively. The latter one will be operative at the frequency range 95 GHz to 3 THz (Terahertz). Since, different spectrum is used, 5G vs 6G technology can have multiple use cases for a variety of industrial sectors to enhance their efficiency.

- **Faster than 5G technology:**

  Taking into the performance factor, 6G will contribute to higher performance which is far better than newly deployed 5G wireless networks. Operating at terahertz frequency bands, 6G will deliver a peak data rate of 1,000 gigabits/s having air latency less than 100 microseconds. When we talk about 5G vs 6G network speed, 6G speed is expected to be 100 times faster than 5G with enhanced reliability and wider network coverage.

- **6G wireless accelerates IoT after 5G**

  Internet of Things (IoT) is becoming a reality today with the implementation of 5G based solutions following extensive 5G network testing which was not possible with previous networks like 4G LTE due to poor planning of frequencies applied. Frequencies used were too narrow and crowded for transmitting data required by smart devices to give desired results. This is where 5G filled in the gap and moving ahead with 6G we expect to connect ten times more devices per square kilometer with increase in number of connected devices in the upcoming years.

- **Low latency in both G's**

  The time taken by a packet of information transmitted over a frequency is known as latency. 4G networks had a latency of about 50 milliseconds (ms) whereas 5G networks had ten times lower latency than 4G i.e., 5ms. With 6G internet, latency will slip down to range 1millisecond to 1microsecond, lowering latency to five times than that of fifth-generation network making massive data transmissions possible in less than a second.

4Gvs 5Gvs.6G: More Than Just Evolutions of Wireless Technology

6G means more than just faster speeds and more data transfer, although those things will exist. When we consider 4G vs. 5G, we can see how wireless technology has evolved. It becomes more nuanced when considering 5G vs. 6G – but that may just be because the technology remains a decade in the future.

Challenges for 5G vs 6G:

With the high-speed development of telecommunication technology, all the industrial partners in telecom make an effort to promote **the digital transformation**. It can be seen that the 6G era is coming in the future.

Compared to the 5G technology, what are the challenges and changes of 6G?

1.From the possibility to the certainty

In the past, the services provided by mobile internet is filled with uncertainties and instabilities because of the specific attributes of Internet Protocol. In 4G era, these services can easily satisfy the subscribers. After all, slight network latency and packet lost could not affect the users experience of watching videos and shopping online.

However, 5G and 6G network will expand to all industries even all things, which requires the certainty of providing low latency and high reliability. This is the reason why network slicing, MEC and relevant technologies is introduced in 5G to offer the end-to-end network services capability guaranteed by (Service-level agreement).

2. Openness and customization

On one hand, as we all know, the key spirit of Internet is openness and sharing, which facilitates the development of Internet. On the other hand, deploying exclusive technology, the ecosystem of mobile communication network limits its evolution to some extent.

Stepping into the 5G era, in order to enable all sorts of industries to be involved in the digital transformation, mobile network should promote the integration of CT and IT positively to help explore more innovative applications in all industries.

The capability of openness and customization will evolve in 6G era, which can support flexible and agile services with the API interfaces for industrial customers to meet the needs of deploying tailor-made network and customized applications.

3.Artificial intelligence network

Nowadays, AI (Artificial Intelligence) has been already applied in several areas such as AI images identification, voice identification, automated translation and so on. For one thing, with the development of network services, higher requirements of network latency, reliability, users experience are needed. For another thing, the more complicated is the network, the more challenging is the process of maintaining and enhancing the network KPIs by traditional operation. To overcome these challenges, operators and equipment vendors are trying to introduce AI into the network to facilitate the network automation and intelligent transformation.

However, it requires massive data and computing resources to exert the value of AI engine at the maximum. Therefore, the future artificial intelligence network in 5G and 6G era needs the interaction between AI and network .

4.100% Coverage

You can lead a convenient and easy life with a mobile phone today, but there are still over three billion people worldwide can not access to the Internet. The failure of constructing network in remote areas is caused by the high cost of deploying base stations and optical fiber cables as well as the geographical condition.

To achieve the goal of 100% coverage in the world, deploying the space-earth integration network is necessary in 6G era. To deploy space-earth integration network, base stations should be set on the platform of upper stratosphere and the LEO satellite, which can fully provide network signal to some remote areas. In general, this solution explores the possibilities of various emerging applications.

5.Terahertz communication

Terahertz frequency band refers to the frequency band **from 100GHz to 10THz**, which will be exploited in

6G era. Having wide bandwidth, it has never been used ever before. That means it can be exploited with no limitations.

However, it is estimated that the terahertz in 6G era will have the same problems as the millimeter wave today: weak capability of covering, high cost of deploying network, the premature ecosystem of terminals and so on, which need to be solved by the whole telecom industry together.

6.Perception and location

For now, the radio spectrum is used by mobile operators to be applied in telecommunication. But in 6G era, radio spectrum can not only be used in telecommunication, but also the function of sensor and location, providing services like communication, environment perception and location tracing, which can enable more emerging applications.

For example:

The radio signals can identify the posture and gesture as well as the surrounding environment to enrich and enhance the user experience.

Maintain the stable operation of smarty city and all industries by perceiving the surrounding environments of moisture, temperature, vibrancy and other elements.

Explore new services with precise location

7. Make the best use of spectrum

As the valuable resource, radio spectrum is the significant carrier of innovation in digital society. In mobile network era, countries create the system of authorizing and distributing spectrum. This system promoted the development of network in the past, but it gradually caused the waste of spectrum.

Therefore, the sharing technology of dynamic spectrum will be studied in 6G era. Introducing AI, block chain and relevant technologies, the wireless industry is trying to control and distribute the spectrum more intelligently and flexibly. Meanwhile, Massive MIMO is evolving to elevating the efficiency of using spectrum.

8. Network security

Network security plays a crucial role in the evolution of digital economy. In 5G era, the 5G value includes

these elements: low latency, high reliability, wide bandwidth and particularly network security.
Entering into 6G era, PQC (Post-quantum Cryptography) as well as QKD (Quantum Key Distribution) and other technologies will be applied in network to ensure the absolute network security.

9. Flexibility, redundancy and self-healing capability

With the diverse applications of 5G/6G in all industries, 5G/6G technology is the solid basis of supporting digital manufacture, operation and administration, which requires higher standard of network reliability and stability.
All roles in telecom industry should devote to constructing a flexible, redundant and self-healing network, which is able to provide stable network services when the network breakdown occurs.

10.Low-carbon transformation

Promoting low-carbon transformation is the joint objective of the world and the essential trend of ICT industry. Confronted with the drastic increasing of network throughput and rising resources consumption, for operators, deploying low-carbon and energy-saving network is the inevitable measure of lowering OPEX and the responsible behaviour of performing social duties.

Comparison of 5G vs 6G wireless Technology

Issue	4G	5G	6G
Per device peak data rate	1 Gbps	10 Gbps	1 Tbps
End-to-end (E2E) latency	100 ms	10 ms	1 ms
Maximum spectral efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Mobility support	Up to 350 km/hr	Up to 500 km/hr	Up to 1000 km/hr
Satellite integration	No	No	Fully
AI	No	Partial	Fully
Autonomous vehicle	No	Partial	Fully
XR	No	Partial	Fully
Haptic Communication	No	Partial	Fully
THz communication	No	Very limited	Widely
Service level	Video	VR, AR	Tactile
Architecture	MIMO	Massive MIMO	Intelligent surface
Maximum frequency	6 GHz	90 GHz	10 THz

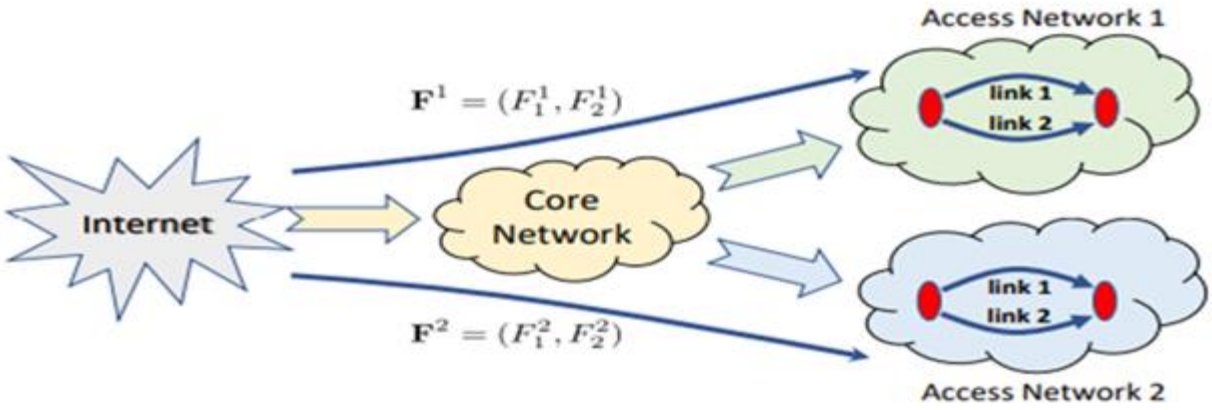
Algorithm:

5G/6G Networks Quality-of-Service Algorithm Developed by NIST Researchers:

5G and 6G networks must provide varying services for such Internet of Things applications as automated manufacturing, vehicle-to-vehicle communications, and remote drone operations – all having differing requirements for data amounts and flow rates. Some of these applications will be very sensitive to data delays.

A significant challenge will be assuring quality of service for user systems at the ends of these networks. NIST researchers have proposed a way to do that in End-to-End Quality-of-Service Assurance with Autonomous

Systems: 5G/6G Case Study, recently published by the IEEE Consumer Communications & Networking Conference



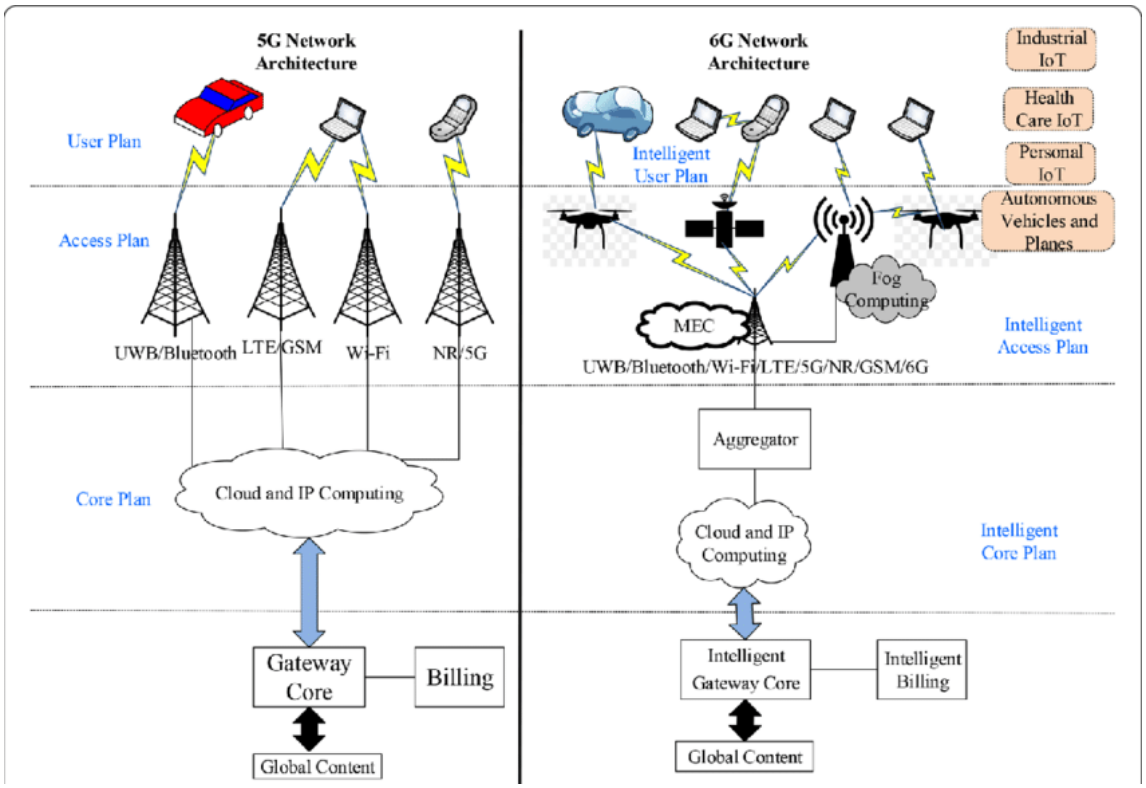
NIST's proposed algorithm enables 5G/6G's core and access networks to coordinate data needs

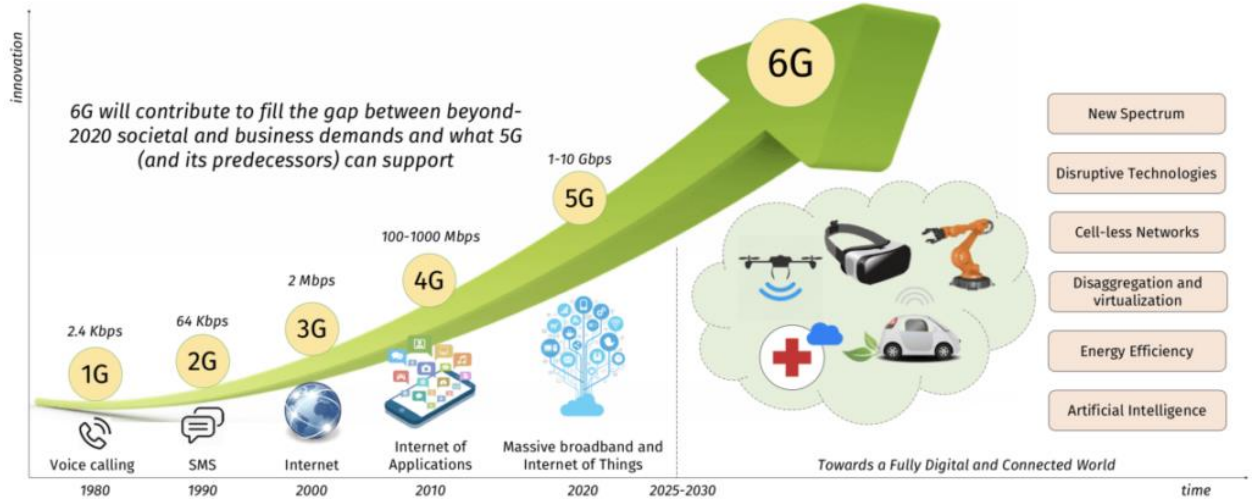
The paper addresses the problem of managing a 5G/6G network's required data flows to multiple user systems, which can be adversely impacted by random events, such as network congestion. This management is challenged by the limited coordination regarding data flows between the 5G/6G network's subordinate networks which autonomously manage themselves. These are:

- Access networks, which wirelessly connect user systems; and
- Core networks, which coordinate some parts of the access network and connects to the Internet.

NIST researchers have developed a framework, which allows these autonomous, subordinate networks to achieve greater coordination among themselves. Specifically, the framework involves an algorithm that allows the networks to negotiate local, needed data amounts. This algorithm also enables these subordinate networks to exchange their estimates regarding overall, global constraint functions.

5G and 6G network Architecture:





Advantages of 5g vs 6g Technology:

Advantages of 5g	Advantages of 6g
Greater number of connected devices	Supports Higher Number of Mobile Connection
High speeds Low latency	Supports Higher Data Rates
Increased capacity	Revolutionize the Healthcare Sector
Greater speed in transmissions	Independent Frequencies
Network slicing	Large Coverage

Disadvantages of 5g vs 6g Technology:

Disadvantages of 5g	Disadvantages of 6g
OBSTRUCTIONS CAN IMPACT CONNECTIVITY	Difficult to use
INITIAL COSTS FOR ROLLOUT ARE HIGH	Expensive

LIMITATIONS OF RURAL ACCESS	Compatibility issues
BATTERY DRAIN ON DEVICES	Privacy
UPLOAD SPEEDS DON'T MATCH DOWNLOAD SPEEDS	Negative Impact on Health

Future of work:

gigabit-per-second communications network known as 5G. The technology promises to deliver not just faster data rates, but a more flexible and programmable network. This will be combined with the high reliability and low latency required to create secure, reliable wireless ecosystems to benefit industries beyond traditional smartphone use-models like manufacturing, transportation, and healthcare.

As many of us are just becoming familiar with the benefits of 5G, technology and communications companies are looking ahead to the next generation, 6G. Although the actual job description of 6G is still being written, the hopes for the technology are to enable a pervasive, seamless internet of things that connects not only people's devices to the network, but allows sensors, vehicles, and many other products and technologies to communicate with each other seamlessly and reliably. For example, having vehicles that can not only communicate to the cloud, but to each other will result in more efficient traffic and safer travel, proponents say.

"6G is not defined, so a great degree of flexibility is needed to help companies navigate potential changes of direction," says says Greg Jue, a 6G system engineer at Keysight Technologies, a testbed provider for advanced technologies. "They require flexibility in being able to change the product, shift development, and then be able to test the new platform."

The differences between 5G and 6G are not just about what collection of bandwidths will make up 6G in the future and how users will connect to the network, but also about the intelligence built into the network and

devices. “The collection of networks that will create the fabric of 6G must work differently for an augmented reality (AR) headset than for an e-mail client on a mobile device,” says Shahriar Shahramian, a research lead with Nokia Bell Laboratories. “Communications providers need to solve a plethora of technical challenges to make a variety of networks based on different technologies work seamlessly,” he says. Devices will have to jump between different frequencies, adjust data rates, and adapt to the needs of the specific application, which could be running locally, on the edge of the cloud, or on a public service.

"One of the complexities of 6G will be, how do we bring the different wireless technologies together so they can hand off to each other, and work together really well, without the end user even knowing about it," Shahramian says. "That handoff is the difficult part."

Conclusion:

Though 6G network is still non-existent and is just in a research phase, enterprises have started envisioning state-of-the-art wireless use cases with 6G technology after successful comparison of 5G vs 6G network. The main aim is to transition in to the new era of wireless technology and bring on new innovations to transform the world in the upcoming years. Highly exciting possibilities with respect to speed and reliability are anticipated to become a reality soon once the new generation of wireless network i.e., when 6G mobile network hits the telecom space on a wider zone. This new-age technology is certainly going to give new dimensions to the way we are living or doing our business virtually today and in the post-covid era, making it as a hyper-connected world.

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