Reducing Inequalities with 5G Internet Light Network Slice

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***Abstract*— So far the 5G mobile systems are mostly known for their superiority in terms of performance, flexibility and cost efficiency but are less known for their social benefit. In this paper, the huge social benefit of 5G is demonstrated through the realization of the Internet Light. The Internet Light is aiming at providing free access to Internet information for all and can be implemented by an Internet Light Network Slice (ILNS) available and accessible to everyone. The paper provides a brief introduction of the Internet Light. After a comprehensive explanation of the 5G network slice concept the elaboration of the ILNS is described thoroughly. A concise description of a Proof-of-Concept is also given.**

Keywords—5G mobile networks, 5G mobile systems, 5G network slicing, Internet Light, Basic Internet, Sustainability Development Goals, Reduced inequalities

I. INTRODUCTION

As the successor of 4G 5G mobile system [1] is well known for its superiority in terms of performance, coverage and quality of service and the promise of enhanced mobile broadband (eMBB) with higher data speed and the support of a wide range of services and applications ranging from massive machine-type communications (mMTC) and ultra-reliable and low-latency communications (URLLC). However, less known but not less significant, are its social benefits. Indeed, the concept of 5G network slicing realized by making use of Network Function Virtualization (NFV) [2] and Software Defined Network (SDN) [3][4][5] can be used to implement the Internet Light concept [6] proposed by the Basic Internet Foundation, which aims at providing free access to information in developing countries for people not able to pay for full Internet service and consequently reducing inequalities. So far, the Internet Light concept is only implemented using wireless LAN 802.11x. This paper presents a solution realising the Internet Light by building a 5G network slice for free access to information, which is experimented at the OsloMet's Secure 5G4IoT Lab [7] within the scope of the H2020 SCOTT project [8]. To achieve its objectives an open source software approach is adopted and an earlier 5G mobile network is constructed by virtualization and cloudification of OpenAirInterface, an open source 4 G/LTE software. The paper starts with a short but comprehensive presentation of the Internet Light concept. Next the state of the art of free access to internet Information is presented and all the competing approaches are summarized. Based on the specifications of the Internet Light the requirements on the Internet Light Network Slice are deduced. The core of the paper is the elaboration of the Internet Light Network Slice using the 3GPP network slice concept. Last but not least is the concise description of the Proof-of-Concept. The paper concludes with a few suggestions of further work.

II. SHORT INTRODUCTION OF THE INTERNET LIGHT CONCEPT

The Internet has nowadays developed into a usable and efficient service that changed the economy. Around 46% of the world's households have access to Internet through either fixed or mobile subscriptions [9]. However, the gap between developed and developing countries is still wide.

Access to mobile networks and feature phones have already increased drastically over the last 15 years, where the proportion of the worldwide population covered by a 2G mobile cellular network grew from 58% in 2001 to 95% in 2015 [10]. A similar growth in access to mobile Internet is expected, but relies on overcoming the main challenges for adoption:

1. *Pricing of phones:* Many people in these regions cannot afford to buy smart phones and seldom use their mobile phones for more than the occasional voice call. Companies such as Micromax, Xiaomi and Google are however trying to meet the challenge of expensive phones by developing low cost handsets targeting these markets' needs [11].
2. *Availability and affordability of data traffic:* The GSM Association (GSMA) has pointed out that by the end of 2014 around 77% of the developing world only had access to no (59%) or narrowband (18%) [12]. Though operators plan for cheaper networks with wider coverage,

there will still be a substantial number of people in the developing world not being able to connect.

3. *Traffic speed:* When connections with less than 2 Mbit/s are the normal situation, access to widely used websites and services, and downloading necessary information becomes cumbersome and sometimes even impossible due to time-outs.
4. *Lack of local content:* It should be relevant for inhabitants in a region and should be in the local language.

The Basic Internet Foundation has been established to support free access to information for all, both on wireless and mobile networks. Free access to information, or the Internet Light solution, is seen as a minor extra cost for the network operator, being either an Internet Service Provider (ISP) or a mobile operator.

The Internet Light network architecture answering the need of a low-cost local infrastructure and rapid deployment is shown in Figure 1. Traffic management and network control centre are the key components of the architecture. The implementation of traffic management comprises two dimensions: (i) provide Internet Light to as many users as possible, and (ii) monitor and manage network infrastructure including a control centre and remote sites. Thus, the infrastructure is divided into two segments: a control centre in Norway and infrastructure in remote sites. The control centre is responsible for authentication and authorization of vouchers or prepaid credits in the account as presently done in the mobile systems. In addition, the control centre operators monitor and manage the network infrastructure in remote sites. The local network consists of a local control centre, a content server and the local distribution. The solution provides high capacity access to local content, paid access for Internet services, and free access to Information.

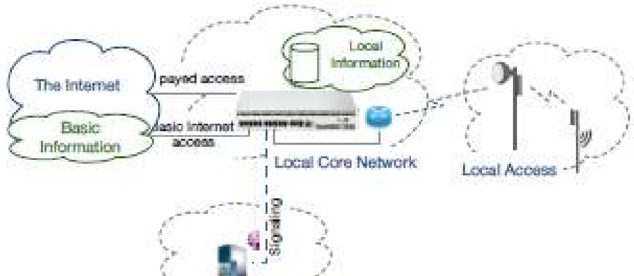

Figure 1. The cost effective Basic Internet architecture.

The Basic Internet control centre monitors local content usage trends in order to forecast and plan required network capacity and local content demand in remote sites. Thus, operators can predict what kind of content should be localized in a remote site in order to manage expensive bandwidth efficiently. Monitoring the Basic Internet network infrastructure also improves the access network efficiency, while reducing operational and troubleshooting costs with network insight. However, monitoring network infrastructure in a location with limited bandwidth imposes implementation challenges regarding monitoring intervals and volume of data collected from the network infrastructure.

The centralised control centre manages network infrastructure remotely so that it reduces the operational and maintenance cost of technical staff at remote locations. The remote management will simplify the network provisioning in remote sites so that new devices that are intended to expand the network can synchronize with the rest of the network smoothly.

Access to free Basic Internet will improve the quality of life of the citizens and empower them with information to generate new or additional income, will make them more productive by saving time, and enable to access healthcare, financial, educational, hospitality, transportation related content and services, and eventually pass these benefits on to their families and next generation to bring overall prosperity for everyone.

The Internet Light has been successfully piloted at the University of Lisala and 4 other universities in Kinshasa, DRC. Three different variants of the product were piloted. These differed in how the access to client devices was provided and what type of backhaul network was used. These were: satellite link, public WiFi access points, and satellite based public WiFi access points. These pilots provided free access to Wikipedia and other educational sites from Cedesurk [13]. The customer infrastructure included a local server, adding free-of-charge educational videos and content. The major goal of the pilot was to bring the students to become Internet users, allowing them to use their own devices to search and use relevant content. The final goal was to leverage 90% of the students to be able to use the local content. An additional goal was to get students become creator of digital content, and digital services providers. This same solution is now being expanded to other countries, such as Tanzania.

III. State of the Art of Free Access to Internet Information

There are currently a few solutions providing free access to Internet information in areas with economic limitations as follows:

A. Free Basics from Facebook and Airtel Zero from Airtel

Internet.org is a partnership between Facebook and several companies to bring affordable access to Internet services. The initiative targets both areas where access is non-existent and areas that have a mobile infrastructure. Non-existent access is provided through local Internet Service Providers (ISPs) using Express WiFi. In areas with mobile coverage, zero-rated content is offered to mobile operators. Zero-rated content are web pages and apps, which are provided free-of charge to the end customer. Free Basics by Facebook is launched in 39 countries, and provides an open platform for providers of apps, websites or services. These can be added to Free Basics as long as they abide by Facebook's participation guidelines that shall ensure acceptable performance on older phones and slower network connections.

A similar platform, Airtel Zero, offers free access to certain mobile applications and services.

Both Free Basics and Airtel Zero has been criticized for violating net neutrality as their approach creates a walled garden around information their users can access. Lately Free Basics has published technical guidelines for efficiency and size, and has thus transferred the evaluation of apps and web sites to objective measures, but it continues to be under Facebook control with no transparency

B. Mozilla's Free Access

Mozilla has targeted the challenge of high prices on handsets by developing a low-cost handset with theirown Firefox OS. In Bangladesh and several African countries they have teamed up with local mobile operators such as Grameenphone and Orange. In Bangladesh, Grameenphone offers the users 20MB of free data per day given that they visit the phones marketplace where users are exposed to advertisements that fund the access. Orange offers buyers of Mozilla's smart phone unlimited free Internet for a set period of time in several African countries. Many countries view the Mozilla approach as captive and forcing the users to certain behaviors dictated by the operators in collusion with Mozilla resulting in stifling competition.

IV. Requirements on the Internet Light Network Slice

The ultimate goal of the Internet Light is to provide non-discriminating access to Basic Information and net neutrality. The solution allows any Internet provider, being it a mobile or an ISP operator, to set up a system where they can provide each user with free access to Basic Information. Voucher sales covers operating costs and allows end users to buy access to more data traffic.

Some of the key technical characteristics of Internet Light are as follows:

- Free information to everyone where the text is delivered in compressed mode and the pictures are in low to medium resolution. Web, Facebook, news are delivered for free without subscription and without the hassle of using username and password. Access to full internet enabling consumption of high capacity content (i.e., bandwidth intensive content, such as video, music, TV, downloads) require authentication for payment by vouchers good for 1 hour, 1 week for consuming 20M, 100M, etc., based on the principle of "I pay for what I need"
- Information is delivered by filtering it, such as the dynamic content is filtered out
- The browser that is supported is Opera Mini running HTTP/2 standard
- Centralized management through open protocols

To realize the vision of Internet Light we propose to implement a 5G network slice dedicated to Internet Light called *Internet Light Network Slice (ILNS)*. There are currently several definitions of network slice which may be conflicting and to avoid confusion we adopt the 3GPP's definition specified in [14] as follows:

A Network Slice is a logical network that provides specific network capabilities and network characteristics.

This network slice must fulfill the following requirements:

- The Internet Light Network Slice must provide a maximum downlink of 6 Mbits/S and a maximum uplink of 3 Mbits, which correspond to a typical data rate of 3G HSPA+.
- There must be modification operation to redefine maximum capacity of the Internet Light Network Slice.
- The Internet Light Network Slice must be capable of supporting a variety of applications such as web browser, social networks, news, education, etc.
- The Internet Light Network Slice must provide mechanism to switch to regular paid network slice upon request by the user for higher QoS (Quality of Service).
- The Internet Light Network Slice must be available and accessible freely by all the users carrying a feature phone[1] or a smartphone.
- The Internet Light Network Slice must be accessible by all the users without differentiation and including the ones without subscription at the providing mobile operators.
- The Internet Light Network Slice should be wherever possible, shared by several mobile operators for achieving high cost effectiveness.
- The Internet Light Network Slice shall grant free access to every mobile phone carrying a valid SIM card issued by any legitimate mobile operator upon successful authentication.
- The Internet Light Network Slice must perform a mutual authentication of the mobile phone to provide better security to the users.
- The Internet Light Network Slice must provide a user-friendly and intuitive authentication scheme.
- The Internet Light Network Slice shall provide sufficiently strong encryption to ensure privacy, confidentiality and integrity of the information exchange session.
- The Internet Light Network Slice must be completely isolated from the other slices such that its operation shall have no impact on other slices.
- The users shall have the ability to change to another network slice by upgrading their mobile subscription.
- The Internet Light shall offer to every citizen an Internet Light subscription with a corresponding Universal Integrated Circuit Card (UICC) aka SIM card free of charge or at affordable fee.

As stated above, to ensure security and privacy of the users, the existence of a valid SIM card and mutual authentication is required. Indeed, without proper authentication it is not

[1] A feature phone is a cellphone that contains a fixed set of functions beyond voice calling and text messaging but is not as extensive as a smartphone. For example, feature phones may offer Web browsing and e-mail, but they generally cannot download apps from an online marketplace.

possible to provide necessary encryption to protect the Internet Light Network Slice.

V. INTERNET LIGHT NETWORK SLICE ARCHITECTURE

A. 5G Reference Architecture

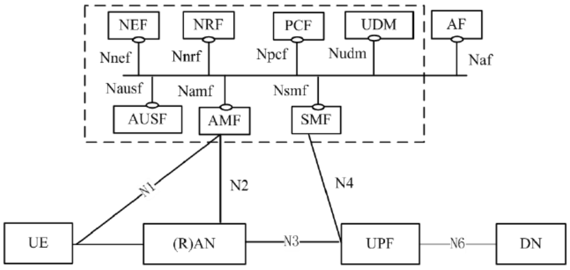

Figure 2 The 5G Reference Architecture (Courtesy of 3GPP)

As shown in Figure 2 the 5G Reference Architecture differs with the 4G architecture not only in their different Network Functions [14] but also in the separation of the User plane and Control plane.

The User plane consists of the following Network Functions:

- **UE** (User Equipment): is the user's mobile phone.
- **(R)AN** (Radio Access Network): is the Access Network Function which provides connectivity to the mobile phone.
- **UPF** (User Plane Function): handles the user plane traffic, e.g., traffic routing & forwarding, traffic inspection and usage reporting. It can be deployed in various configurations and locations depending on the service type.
- **DN** (Data Network): represents operator services, Internet access or 3rd party services.

The User plane consists of the following Network Functions:

- **AMF** (Access and Mobility Management Function): performs access control, mobility control, transparent proxy for routing SM messages.
- **AUSF** (Authentication Server Function): provides authentication functions.
- **UDM** (Unified Data Management): stores subscriber data and profiles. It has equivalent role as HSS in 4G but will be used for both fixed and mobile access in 5G core.
- **SMF** (Session Management Function): sets up and manages the PDU session according to network policy.
- **NSSF** (Network Slice Selection Function): selects the *Network Slice Instance* (NSI), determines the allowed *network slice selection assistance information* (NSSAI) and AMF set to serve the UE.
- **NEF** (Network Exposure Function): exposes the services and capabilities provided by the 3GPP network functions.
- **NRF** (NF Repository Function): maintains NF profiles and supports service discovery.
- **PCF** (Policy Control function): provides a policy framework incorporating network slicing, roaming and mobility management and has equivalent role as PCRF in 4G.**AF** (Application Function): interacts with the 3GPP Core Network (CN) to provide services.

B. Designing the Internet Light Network Slice (ILNS)

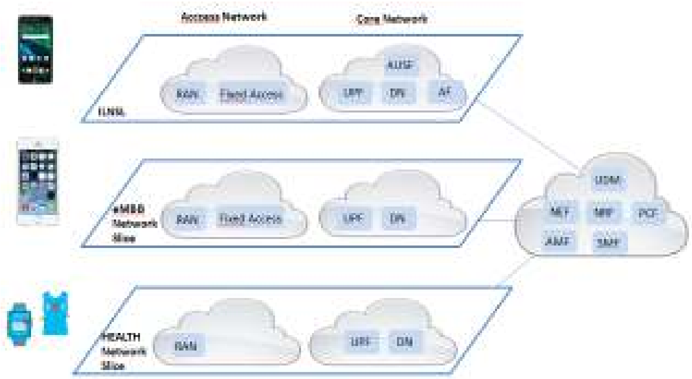

Figure 3 Internet Light Network Slice Architecture

As shown in Figure 3, to ensure isolation, ILNS will be realized as an end to end network slice, i.e., it is comprised of Network Functions (NF) instances for the access network such as RAN, Fixed Access and for the core network such as UPF, DN. While most of the NF instances of the control plane are shared with the other network slices in order to allow the user to upgrade and switch to other network slices with higher QoS.

To identify ILNS a Single Network Slice Selection Assistance Information (S-NSSAI) is defined with Slice/Service type (SST): **`MIoT`** (Massive IoT) and SST value: **`3`**. It is worth noting that although the slice type is MIoT it is as specified by 3GPP sufficient for Internet Light because MIoT slice has a minimum downlink of 50 Mbps and minimum uplink of 25 Mbps.

To enforce the maximum downlink and uplink bit rates of the Internet Light specified earlier in section IV each User Equipment (UE) or mobile phone is associated with an aggregate rate limit QoS parameter called **`UE Aggregate Maximum Bit Rate (UE-AMBR)`** [14]. The `UE-AMBR` limits the aggregate bit rate that can be expected to be provided across all Non-GBR (Non-Guaranteed Bit Rate) QoS flows of a UE.

The ILNS RAN instance shall set its `UE-AMBR` to the sum of the Session-AMBR of all PDU (Packet Data Unit) Sessions with active user plane to it up to the value of the ILNS UE-AMBR. The ILNS `UE-AMBR` is a subscription parameter which is defined per default for all users by the mobile operator, and is retrieved from UDM and provided to the RAN by the AMF. The UE-AMBR is measured over an averaging window with a standardized value.

C. Access to ILNS

To clarify how the mobile can get access to ILNS, we provide a registration procedure which is simplified for the sake of clarity as shown in Figure 4.

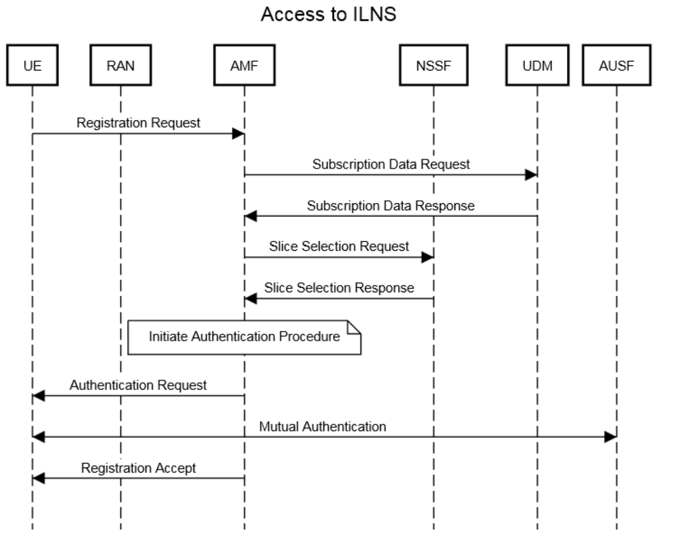

Figure 4 Mobile phone access to ILNS

1. When a UE registers with a public land mobile network (PLMN), if for this PLMN the UE has no Configured NSSAI or Allowed NSSAI, the RAN shall route all Non Access Stratum (NAS) [15] signaling from/to this UE to/from the default AMF including the UE Initial Registration request.
2. The AMF queries the subscription data from the UDM.
3. The UDM sends the subscription data back to the AMF.
4. If the user has another subscription than Internet Light, the subscription data will contain a subscribed S-NSSAI and the AMF will send to the NSSF a Slice Selection Request including this subscribed S-NSSAI and UE location.
5. If the user does have any other subscription the AMF will send to the NSSF a Slice Selection Request including ILNS as subscribed S-NSSAI and UE location.
6. The NSSF determines the allowed NSSAI which can be ILNS or the subscribed S-NSSAI and sends back to the AMF Slice Selection Response.
7. The AMF initiates now the authentication process.
8. The mutual authentication is carried out between the UE and AUSF.
9. Upon successful authentication AMD sends a Registration Accept to the UE.

The mobile phone AKA UE is now connected to the ILNS.

VI. The Internet Light Network Slice Proof-of-Concept

To validate the concept of Internet Light Network Slice we decided to build a proof-of-concept (PoC), shown in Figure 5, using open source software and software defined radio at our Secure 5G4IoT Lab [16]. There is currently no 5G open source software available but fortunately there is an excellent 4G/LTE open source software, namely **`OpenAirInterface (OAI), [18]`** that is adopted in our proof-of-concept. As explained in [17], the 5G system will not only be about delivering higher data rates using enhanced wireless radio technologies but also softwarisation and virtualization of the mobile network. Indeed by virtualizing OAI we can obtain an earlier version of 5G systems, which is very satisfactory because it enables experiments on Network Slicing and also realizing an Internet Light Network Slice Proof-of-Concept.

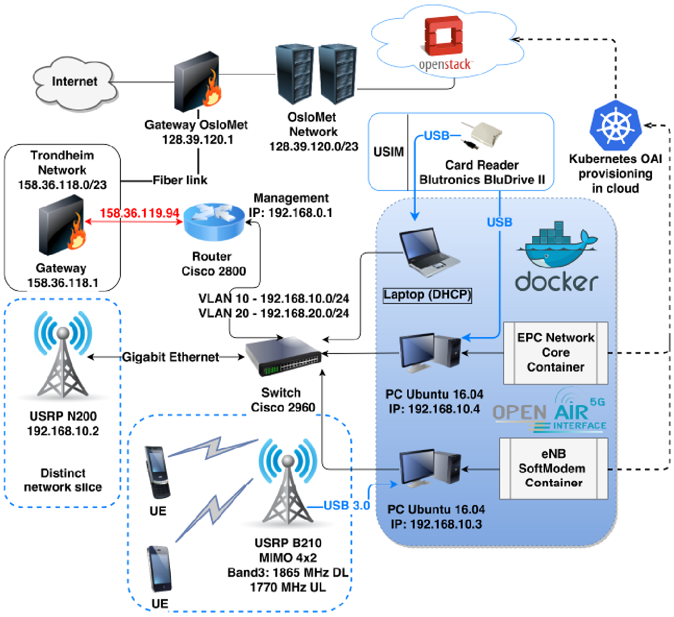

Figure 5 The Internet Light Network Slice Proof-of-Concept

At first, we focused on running OAI on hypervisors like KVM (Kernel-based Virtual Machine) [19], VirtualBox [20] or VMware [21] but encountered rather soon a few problems. The major obstacle of virtualization is the overhead, as well as complexity introduced by the additional layers of abstractions. To solve the issue of overhead we choose to use containers instead of virtual machines.

Containerization [22] also called container-based virtualization and application containerization is an operating system level virtualization method for deploying and running distributed applications without launching an entire VM for each application. Multiple isolated systems, called containers, are instead run on a single control host, accessing a single kernel. At the Secure 5G4IoT lab, we adopt a configuration which uses a separate container to deploy the entire EPC, as well as another one for the eNB, as shown in figure 5. There are few container implementation possibilities, but in our Proof-of-Concept, Docker [22] is used for the containerization of the OpenAirInterface.

As shown in figure 5 the PoC consists of the following nodes:

- **EPC:** 192.168.10.3; PC running Ubuntu 16.04
- **eNB:** 192.168.10.4; PC running Kali Linux connected via USB 3.0 interface to a Universal Software Radio

Peripheral (USRP) B210 [23] and via Ethernet with a USRP N200.

- Two smartphones Huawei P9 lite, equipped with self-programmed Milenage algorithm SIM cards
- Blutronics BluDrive II SIM card programming device
- Cisco 2800 router and Cisco 2960 switch, separated in two VLANs

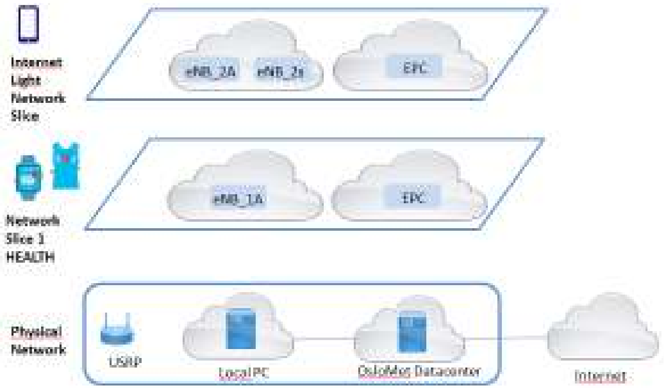

Figure 6 Network slicing at Secure 5G4IoT Lab

The PoC is situated at Oslo Metropolitan University, where a dedicated cloud infrastructure is built in a datacenter. As shown in Figure 6 two network slices, namely Health and Internet Light are instantiated on the same physical infrastructure and slice isolation can be verified.

VII. Conclusions

In this paper another benefit of 5G, which is so far not well explained but nevertheless quite important, namely its social benefit, is demonstrated in a clear manner. Indeed, 5G systems can contribute to the realization of the Internet Light which is aiming at reducing inequalities in the world by providing free access to information for people in the developing world world. The 5G Network Slice concept can be used to implement the Internet Light in a cost effective, flexible, secure and manageable way. An Internet Light Network Slice Proof-of-concept is successfully implemented. Although the QoS aspects have been ignored for the time being due to the lack of proper 5G implementation, the isolation, security and flexibility of the Internet Light Network Slice have been experimented and validated. For further works, it might be relevant to extend the Proof-Of-Concept at the lab to a field trial in which real users can participate and give feedback. Another major achievement is to deploy an Internet Light Network Slice on real 5G trial deployment such as the one that Telenor will do in the Kongsberg commune in Q4 2018.

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