Sustainability Research of the Secure Wireless Communication System with Channel Reservation

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Abstract—**The paper presents the research of the stability of the system with redundancy of communication channels. For this, two prototypes have been developed that are built (1) according to the classical circuit-switched scheme and (2) with aggregation of several virtual channels. Prototyping, installation on various vehicles and measurements of the stability of the entire system as a whole were carried out. The paper also presents structural diagrams, hardware, and a list of problems and difficulties that the authors encountered during the practical implementation and implementation of these systems. In the future, it is planned to expand the study of these systems when working with high-level channel virtualization and the search for methods to accelerate its work.**

Keywords—channel reservation; wireless; sustainability.

I. INTRODUCTION

The work of modern wireless public access systems contains a number of vulnerabilities, therefore, solutions to the problem of simultaneous transmission of secret data and at the same time maintaining a stable connection require the use of special network solutions. These solutions are possible due to the switching of virtual channels, which can be distributed among different telecommunication service providers. The problem of reservation of communication channels can be solved by aggregation of several virtual channels. The more mobile operators work in the same territory, the higher the chances of getting uninterrupted access to remote services.

For high-quality channel switching, an external subsystem for monitoring the signal level in each of the wireless systems can be used [1].

The paper is structured as follows. Section II gives an overview of related works. In section III, has presented our vision of the work of requirements to it. Section IV gives an overview of software and related hardware used during development of two prototypes. Section V presents results of the testing of our developed complex. This paper ends with section VI were concluded current state of development of this system and described directions of future development.

II. RELATED WORKS

Virtualization in various sources is considered from different angles. For example, in [2] channel reservation is defined to reserve several fixed channels only for primary users, which will lead to less frequency spectrum handoffs comparing with no reservation mechanism. To manage the queue in [3], it is proposed to use FIFO scheduling aggregates flows into a single flow just prior to the wireless link, channel-state dependent schedulers maintain a queue for each flow.

For the formation of the organization of the virtual environment, groups of researchers suggest using different protocols: Adaptive Genetic Algorithm for identifying the shortest path [4]; Multi-Step Channel Reservation based on Multi-Channel MAC protocol for solving the bottleneck problem [5]; Backup Channel Reservation Protocol for reconstructing of the second communication if forced termination occurred [6] and Secured Traffic Priority Differentiation (at MAC sub layer) for support any application [7]. General principles for protecting wireless networks with virtualization are presented in [8]. And in [9] it is shown that clustering of the sensor network can be used as a client network.

III. RESERVATION LOSS

The probability of k packets arriving in time T is modeled as:

$$P(k) = \frac{(\lambda T)^k e^{-\lambda T}}{k!}, \tag{1}$$

where λ is the packet arrival rate in a station [10].

System requirements contain mutually exclusive clauses; therefore, a solution can only be a compromise:

- Work in mobile public networks.

- Use of available hardware base.

- The data transfer speed is sufficient for video teleconferencing.

- Ensuring stability of work on moving objects.

- System mobility.

- Minimal use of mobile traffic in standby mode.

- Minimum visibility of additional antennas when placed on vehicles.

- Electricity consumption from regular vehicle power sources.

- Scalability and ease of configuration.

IV. PROTOTYPING

The first prototype of the device was assembled according to the simplified scheme shown in Fig. 1.
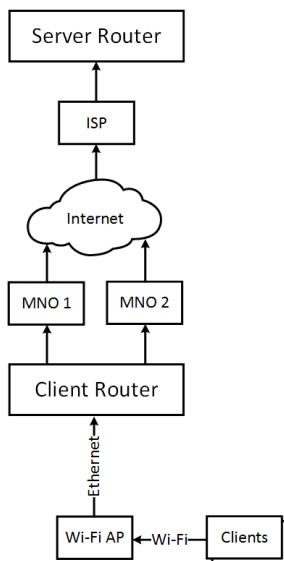

Fig. 1. Structural scheme of the first prototype.

To solve the problem of a stable Internet channel for transport, the classical channel reservation scheme was used, i.e. a router with two WANs and switching between them when the main channel is broken. The following equipment was selected:

- Two Huawei B880-75 modems

- Cisco RV042 router

- Mikrotik Wi-Fi hotspot

Modems are connected by Ethernet ports to WAN1 and WAN2 of the Cisco router, and the access point is connected directly to the router (Fig. 2).

The channel switching logic is as follows: WAN1 acts as the primary channel, WAN2 as the backup. Through WAN1, Google DNS is periodically requested by the IP address 8.8.8.8, and in case of ICMP packet loss, the router reconnects to the Internet through WAN2.

Fig. 2. The first prototype portable client station with two LTE modems.

The main problems of this implementation:

- Unstable switching speed (from 20 to 60 s).

- Frequent false positives. When the car was moving, the loss of ICMP packets was periodically recorded, due to which the Internet was constantly switching from one WAN to another.

- Due to the change of mobile providers, the external IP address also changed, because of which there were problems with sessions in some online programs on clients. For example, messengers lost contact with the server and switched after a few minutes, and sometimes completely hung in standby mode until they were manually restarted.

Huawei B880 modems are not designed for mobile movement, so if the base station was lost, they could not always correctly find another and connect. As a result, when turned on, the modem refused to find the base station (in some cases, a reboot helped).

These problems have become a decisive factor in the search for other channel redundancy solutions.

The next implementation involves the use of wired aggregation logic through mobile operators. This approach solves the problem of connection stability (Fig. 3). After analyzing coverage maps of various mobile operators, it was decided to expand the number of backup connections to four to ensure more stable operation.

The following equipment was selected:

- Four Huawei B880-75 modems

- Mikrotik RB951Ui-2Hnd router

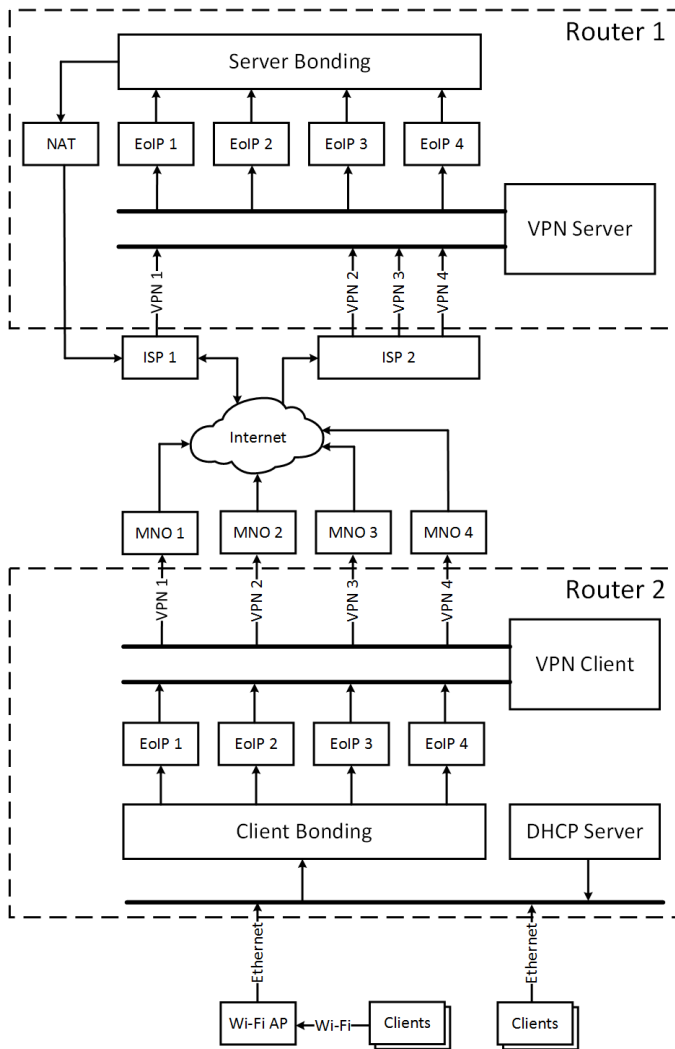- Apple Airport Express Wi-Fi hotspot

Fig. 3. Structural scheme of the secure wireless communication system with channel reservation.

The algorithm for starting services and connections:

1. Four VPN connections with the server are launched.

2. Each VPN connection is routed through its WAN.

3. Based on the assigned IP addresses of the VPN connections, four EoIP tunnels are launched on the server side and client side.

4. Bonding service is launched, which aggregates four EoIP tunnels from the server and client.

As a result, the server and the client see each other as if they are connected by the same cable to each other. For connected end devices, the gateway is the Mikrotik server, which routes traffic through NAT to the Internet (Fig. 4).

The advantages of this implementation:

- Stable connection while running at least one VPN channel.

- There are no switches for clients, since the same external IP address is always used.

- The ability to raise OpenVPN on top of Bonding and encrypt all traffic from the car to the server.

- Remote traffic monitoring, aggregation management and VPN connections.

Fig. 4. Portable client station industrial design.

Among the design flaws remain:

- Low speed Internet traffic, no more than 5–6 Mbps, which (does not depend on the speed of mobile connection).

- The need to use a server with a white IP address.

- High power consumption of the equipment (more than 50 watts), which necessitates high-quality switching of power supply and cooling devices.

- The bulkiness of the equipment and the complexity of its placement on the vehicle.

- The need to install antennas on the roof of the car and lay the cable to them.

The total cost of the second prototype exceeded the first three times.

V. IMPLEMENTATION

The implementation of this system was carried out on three vehicles that were used within the access network. Each assembly was individual and implied the use of different buildings, as it was installed on vehicles of different brands.

To connect to the Mobile Network Operator (MNO), Huawei B880-75 devices were used, in which the maximum download speed in 4G mode was 70 Mbps (with a theoretical of 150 Mbps).

Client hardware was installed on fixed and moving objects. The maximum data transfer rate was 6 Mbps for stationary

objects, and when installed on a vehicle at a speed of 160 km/h, the speed sagged up to 1 Mbps.

This switching device can be installed on armored vehicles, the metal thickness does not affect the quality of communication, since external antennas were used during operation: two stationary LTE/3G antennas (800/900/1800/2100/2600 MHz) with a gain of 5 dB and vertical polarization and two additional GSM/3G antennas (850/900/1800/1900/2200 MHz) with a gain of 5.5 dB, vertical polarization, standing wave ratio less than 1.5:1 and a maximum input power of 20 watts.

In conditions of poor communication quality, an accelerating lens can be used to focus the antennas towards the base station [11, 12].

Partially resolved the problem with the modems freezing when turning on the power. The equipment was connected to the cigarette lighter socket, which was disconnected through the ignition system. When the car stopped, the ignition was turned off and at the next start, the modems worked. Nevertheless, there was no guarantee that all modems would still start correctly.

Aggregation required constant ping (sending of ICMP packets), therefore a small traffic of mobile operators was constantly spent.

An additional power switch is required if the equipment is not connected through the vehicle's ignition system.

To connect end users, you can use access points that solve the "last mile" problem. In this case, we used a Wi-Fi access point Apple airport express with a redo matching the input voltage for 12 V (Fig. 5).
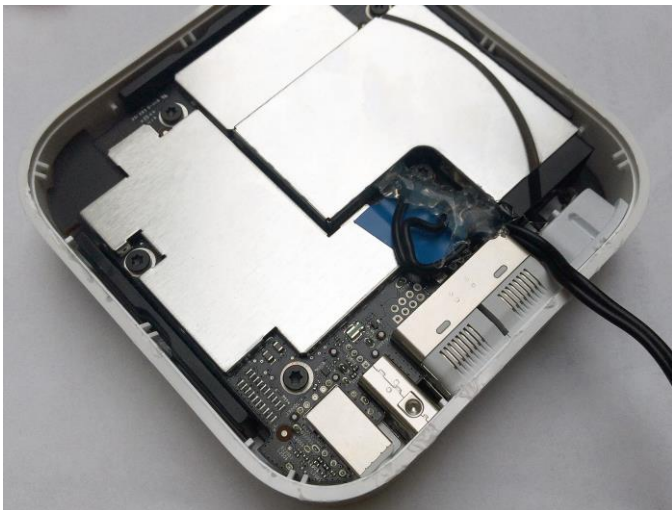

Fig. 5.   Adaptation of the access point to an autonomous power source.

To increase the speed of work, the simplest protocols should be used. One of these protocols is the Point-to-Point Tunneling Protocol (PPTP), using which there is minimal loss in transmission speed.

This system can be used as part of a virtual network in which virtualization is used at a higher level, for example,

using OpenVPN. Thus, this switching system is encapsulated inside another virtual system.

Keep in mind that each virtualization layer reduces the final data transfer rate. It is necessary to prevent a decrease in speed below the minimum value that ensures the operation of a set of services.

VI. CONCLUSION AND FUTURE WORK

Redundancy in wireless communication channels increases stability, but does not lead to a three to four-fold increase in the cost of such a system. In addition, due to aggregation of channels, the speed of the entire system decreases by an order of magnitude and usually does not exceed the speed of the slowest channel. As practice has shown, this system with redundant channels allows you to implement a secure communication channel on the basis of the existing commercial cellular infrastructure, which will be simultaneously distributed among several communication channels, encrypted and stable. A data transfer rate of 5–6 Mbps allows you to transfer secret data (documents and media files), as well as produce voice and video teleconferences in real time.

In the future, the authors intend to conduct experimental studies of the stability of this system in conditions of poor quality wireless systems. In the future, it is planned to use additional virtualization on top of the system with redundancy.

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