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Improving quality of service in Worldwide Interoperability for Microwave Access networks using Relay nodes

Abstract. In WiMAX networks, two main forms of propagation models are used. These are the non-line of sight propagation (2GHz to 11GHz) and line of sight propagation (2GHz to 11GHz). It is expected that WiMAX operators will need to increase the density of base stations in order to properly address the challenges posed by the mobile non-line of sight propagation channels. Therefore in order to enable rapid and cost effective deployment of WiMAX networks, relay technology, which requires no back-haul line, is considered a key feature for successful business. This study evaluates the power deployed by the direct link for communication, that is, a user equipment communicating via the home base station and the use of a foreign base station as a relay point to communicate with the home base station. The varying parameter for this study is the distance between the user equipment and the base stations. An algorithm was used to choose the best possible route for communication with respect to the user's distance to the base stations. In the findings, the relay method proposed, yielded a difference of 21.5175dB from the direct link. This is a 10% decrease in power with respect to the direct link.

Keywords: Worldwide Interoperability for Microwave Access; relay station; power; Quality of service; Rayleigh distribution; foreign base station; home base station.

Introduction

In the past when there was no electricity or any form of communication circuit in existence, information was sent via messengers across, towns, cities and provinces or empires. The safeties of these messengers were by obvious means, not guaranteed. As time went on, the kings of Babylon came up with a strategy of putting in place, guard post at regular intervals on the royal roads to the empires. Interestingly, little did they know that they were coming up with a phenomenon which was going to develop the system of relay [1]. Relay has been in existence for a very long time, not necessarily in networks but in relatively natural forms. A more electrical approach to relay was formulated by the introduction of the Morse code in 1840. [2] It was used to repeat the signal coming in from one circuit and retransmitting it to another and thus allowing signals to be propagated as far as desired. This overcame the problem of limited range of earlier telegraph scheme. The original Morse design, without the relay or intensity electromagnets invented by Vail, only worked to a distance of 12 meters. In 1877, all rapid long-distance communication depended upon the telegraph. That year, a rival technology was developed and changed the face of communication: the telephone. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

Relay in WiMAX

In WiMAX, there are two forms of wireless services: the non-line of sight Wi-Fi sort of service where a small antenna on a computer connects to the tower. This form uses lower frequency range (2GHz to 11GHz) similar to Wi-Fi, and the line of sight service where a fixed dish antenna points straight at the WIMAX tower from a rooftop or pole. Line of sight transmissions use higher frequencies with ranges reaching a possible 66GHz. [3] It is expected that WiMAX operators will need to increase the density of base stations in order to properly address the challenges posed by the mobile non-line of sight propagation channels. Therefore in order to enable rapid and cost effective deployment of WiMAX networks, relay technology, which requires no backhaul line, is considered to be a key feature for successful business [4]. There are two types of relay station modes. The transparent relay station (T-RS) which does not transmit a preamble and it does not broadcast control messages such us downlink map (DL-MAP). A mobile station (MS) physically connected to a T-RS receives broadcast signals directly from the multi-hop relay base station (MR-BS) and is not aware of the existence of the relay station (RS) (no logical connection). T-RS relays only data traffic. The second relay mode is the non-transparent relay station (NT-RS) which operates as a base station (BS) for a connected MS. The NT-RS transmits a preamble and other broadcast messages and relays data traffic as well. An MS is physically and logically connected to an NT-RS. [5]

Previous work

In [6] [7], they proposed a relay technique for the purpose of reducing uplink transmit-power in GSM networks. In their scenario a Base Station (BS) of a foreign network provider (FBS) serves as a relay node between a Mobile Station (MS) and the base station of its registered home network (HBS). After analyzing the theories behind power received and power transmitted with respect to distance, frequency of operation and channel conditions, the formulas derived from these theories have been used in developing algorithms for the normal operation between a Base Station (BS) and a User Equipment (UE) of the same network. These parameters were considered in developing an algorithm for the relay technique scenario in this work. The methodology they used was that, under the assumptions of the existence of an agreement between two different operators, having their base stations in line of sight to share their air interfaces, an algorithm is designed to choose between two paths, a direct link and a relay link, based on the transmit power by the MS. The direct link is the normal path between a MS and its registered Home Base Station. The relay link is made up of the path between a MS and a Base Station of a foreign network provider (FBS), and the path between the foreign base station and the home base station. The power required for transmission over the relay link and the power required for the direct link are computed under the various channel conditions; the link with the least power is used by the MS to transmit signal to the home base station HBS, hence increasing battery life and a longer functionality time for MS. The scenarios were simulated using Matlab. The results revealed that the transmit power from the mobile station to reach the HBS using the relay link is much lower than the transmit power from the mobile station using a direct link to reach the HBS, when the mobile user is closer to the FBS than to the HBS. In addition, the relay technique is more efficient with low received power applications such as voice and less efficient with high-received power applications such as data. Furthermore, when the shadowing environments is not favorable for the relay link, transmitting using the air interface between mobile station and FBS still reduces transmit-power of the mobile station. The results also showed that path loss exponent is a more predominant factor for the transmit-power than the shadowing. The study only focused on uplink transmit power and was implemented in GSM networks. It is useful in our study since it defines the relay technique principles that will be implemented in our work using WiMAX networks.

In [8], Y. P. Kim highlighted problems such as coverage holes due to shadowing and poor signal to interference and noise ratio for the subscribers' stations that are far away from the base station. To address the above problem the author in this article mentioned the idea of deploying low cost relay stations, which do not require backhaul connections, as an alternative to adding base stations, which may be an inefficient solution especially where there are few SSs. The author also highlighted the IEEE 802.16j amendment, which focuses on the deployment of RS in such a way that, the network capacity can be enhanced, or coverage of the network can extended. In the first part of their work focused on improving cell capacity by deploying T-RSs inside a cell, and considered the placement of RSs that maximizes cell capacity. They also showed how various network parameters such as reuse factor, terrain types, RS antenna gain, and the number of RSs affect the optimal placement of RSs and the capacity gain compared to the conventional scenario (i.e without RSs). In the second part of the work, the focus was on deploying NT-RSs for the purpose of coverage extension. Three different issues were investigated. First, several scheduling schemes such as orthogonal, overlapped, and optimal schemes were studied in order to maximize cell throughput while serving the SSs in a fair manner. Secondly, cell coverage extension was analyzed by varying both the location and number of RSs from a cost efficiency perspective. Finally, an extension of the optimal scheme was explored to a general multihop-relaying scenario, and analyzed the network throughput degradation due to the increase of relay hops under the optimal scheduling scheme. The general conclusion was: the lower the cost the lower the cell throughput; however, a higher cell throughput can be achieved with relatively lower cost by carefully choosing both location and number of users. However one limitation of their work is that they did not consider the impact of the numbers of relay stations on the network performance and also the problem of noise amplification at relay stations which will be considered in this work.

Methodology

A. Assumption

For our study, it is assumed that the foreign base station is placed at midpoint from the user equipment (UE) to the home base station (FBS) and the communication from the UE to the HBS is hindered by poor quality of service as shown in figure 1.

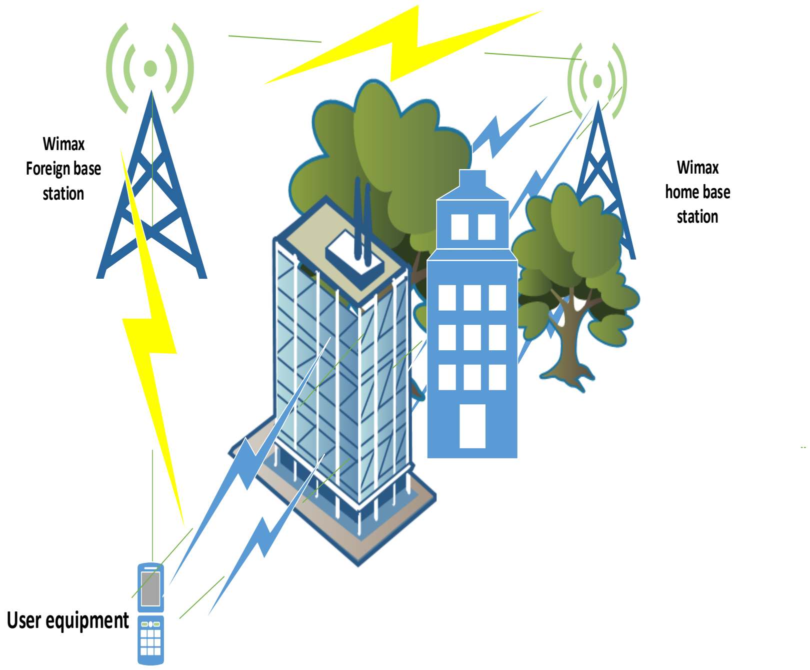

Fig. 1. *Architecture of assumed relay station model*

In this relay model, the quality of service on the network is not suitable for effective communication to the home base station (HBS); therefore, the transmission is routed through a foreign base station (FBS) that belongs to a different network operator. If the FBS is in line of sight with the HBS then the transmission is established through air interface between the mobile station and the HBS. [9]

- THE RELAY SCENARIO
  - HBS and FBS are in Line of Sight (LOS);
  - FBS is within the geographical coverage area of HBS;
  - Both operators have agreed to share base stations as a relay node when necessary after an authentication process;
  - FBS is located halfway between MS and HBS.

B. Relay link Power

Relay link power is the total power deployed to reach the HBS using an FBS as a relay node [10]. The relay link power is the addition of two transmitted power in dB:

- The transmitted power from MS to the FBS;
- The transmitted power from the FBS to reach the HBS.

1) Power from MS to Foreign BS

Let's denote it by

$$P_{fbs-hbs}[dB] = 10 \cdot \log(P_{rhbs}) - 10 \cdot \log(K) + 10 \cdot \eta_{fbs-hbs} \cdot \log(r_{fbs-hbs}) - 10 \cdot \log(X_{fbs-hbs}) \quad (1)$$

Where:

- P_{rfbs} is the receive power by the Foreign Base station;
- X_{ms-fbs} is the Fading effect along the path of MS and FBS which follows a Rayleigh distribution;
- Y_{ms-fbs} is the Shadowing effect along the path of MS and FBS which follows a Log-normal distribution;
- r_{ms-fbs} is the distance between MS and the FBS;
- η_{ms-fbs} is the pathloss exponent;
- K is a constant.

Therefore, if we denote P_{rlp} as the relay link power, it will be equal to:

$$P_{rlp}[dB] = P_{ms-fbs}[dB] + P_{fbs-hbs}[dB] \quad (2)$$

When we replace the different variables by their equivalent values, equation (2) becomes:

$$P_{rlp}[dB] = \{10 * \log(P_{rfbs}) - 10 * \log(K) + 10 * \eta_{ms-fbs} * \log(r_{ms-fbs}) - 10 * \log(X_{ms-fbs}) - 10 * \log(Y_{ms-fbs})\} + \{10 * \log(P_{rhbs}) - 10 * \log(K) + 10 * \eta_{fbs-hbs} * \log(r_{fbs-hbs}) - 10 * \log(X_{fbs-hbs})\} \quad (3)$$

C. Relay flow chart description

In case the quality of service defined for a mobile station to transmit over the home base station is not met, the algorithm represented by the flow chart in figure 2 will be used. The number of users are randomly generated by varying the distance between MS and HBS. Firstly, the power deployed by the mobile station to reach the home base station is evaluated as well as the power deployed by the mobile station to reach the foreign base station. Therefore, the FBS is being used as a relay node. A graph is then created to show all the parameters for both cases: using the HBS and the FBS for transmission. Finally a throughput graph of the model is generated.

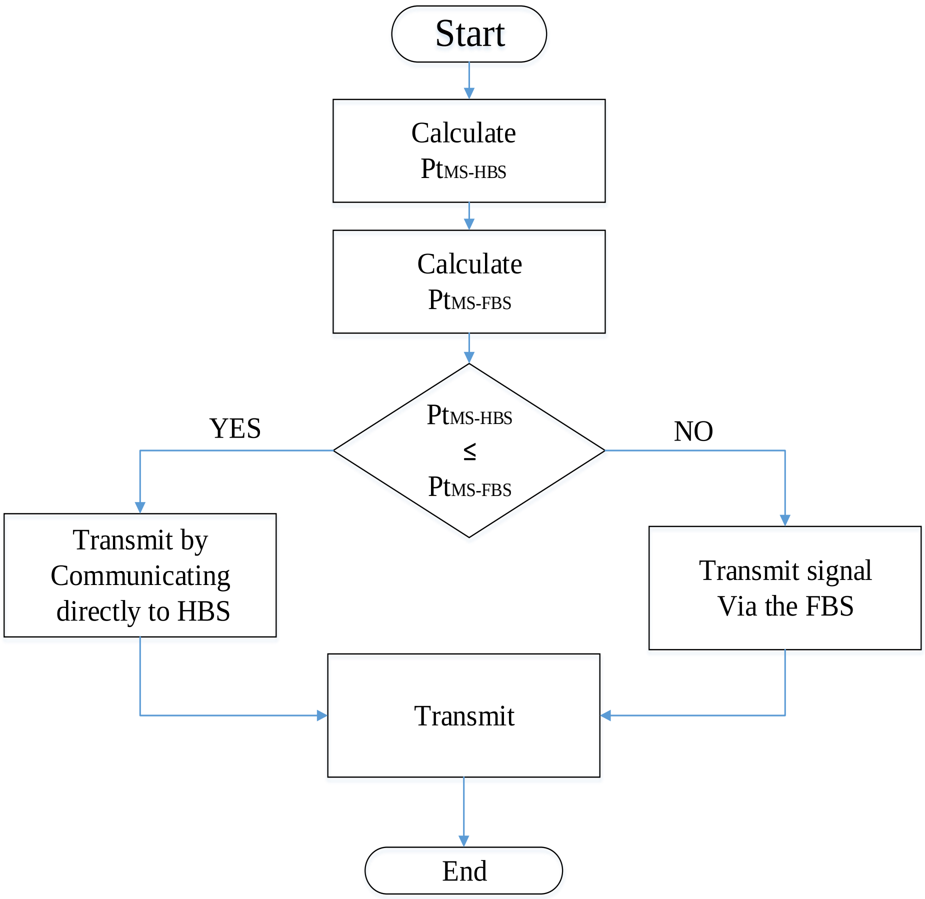

Fig. 2. *Relay approach flow chart*

$Pt_{ms\text{-}hbs}$ is the power deployed by the mobile station to reach the home base station.

$Pt_{ms\text{-}fbs}$ is the power deployed by the mobile station to reach the foreign base station.

Pb_{fbs} is the blocking probability of the foreign base station system.

Pb_{hbs} is the blocking probability of the home base station system.

f1 is the function that combines both $Pt_{ms\text{-}hbs}$ and Pb_{hbs}.

f2 is the function that combines both $Pt_{ms\text{-}fbs}$ and Pb_{fbs}.

Results

The power needed to transmit data in a cellular network is related to the obstacles between sender and receiver. The average power used by the 1000 users in each subdivision, using the direct-link and the relay link is calculated. Two scenarios are simulated here; firstly, a plot of power using direct link (from MS to HBS) and power using relay link (from MS to FBS) done. An algorithm is designed such that it chooses between the first two scenarios; the one that uses the least power at every 1km. (ALGO LINK). Matlab 2012 was used to simulate the algorithms and the results are shown in the graphs below.

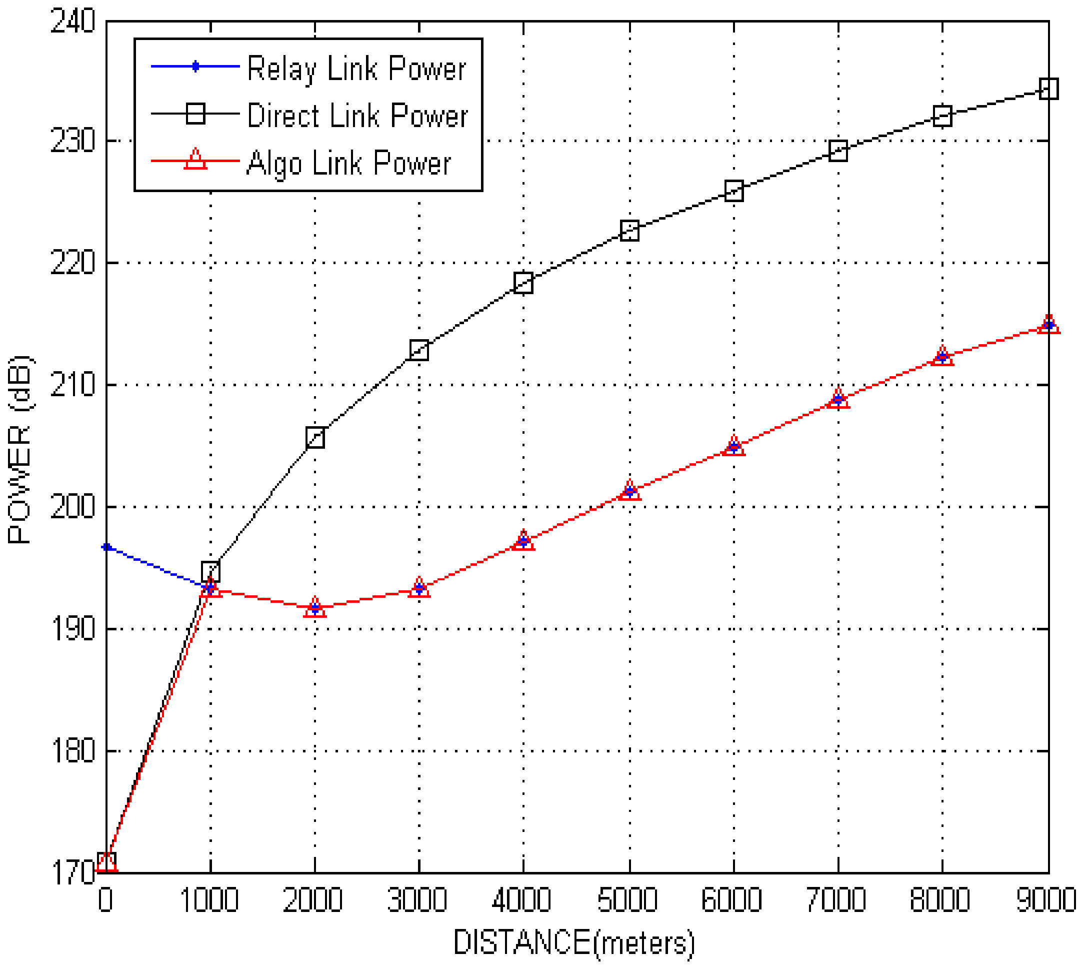

Fig. 3. *Relationship between distance and route taken by algorithm*

- Before the first kilometer the power needed to reach the foreign base station for data transmission is more than that needed to reach the home base station. Therefore the algorithm will pick the direct link (from MS to HBS) as shown in figure 3. This is due to the fact that the users are very close to the base station.
- However it is noticed that from the 1000 meter region, the algorithm switches to the relay link (that is, from MS to FBS then to HBS) which uses less power to transmit data. This occurs because users in this zone are closer to the FBS than HBS.
- Further than 1000m, the algorithm still selects the foreign base station as the best alternative for communication. Even though the power needed in this case has exponentially increased, it is still lower than that requested for a transmission through the home base station. Subscribers in this zone are getting farther from the HBS.
- Here below is a table 1, which shows the power value differences between direct link and algo link. According to that table 1, a chart outlining the difference between the power values is done in figure 4.

TABLE I

POWER DATA COLLECTIONS WITH THEIR DIFFERENCES

DIRECT POWER (dB)	ALGO POWER(dB)	Power Diff(dB)
170.0079	170.0079	0
194.3079	193.0829	1.225
205.2478	191.2333	14.0145
212.81	193.116	19.694
217.9282	196.4425	21.4857
222.6641	201.1466	21.5175
226.045	205.0119	21.0331
229.4015	208.9353	20.4662
231.8288	211.9407	19.8881
234.2481	214.8693	19.3788

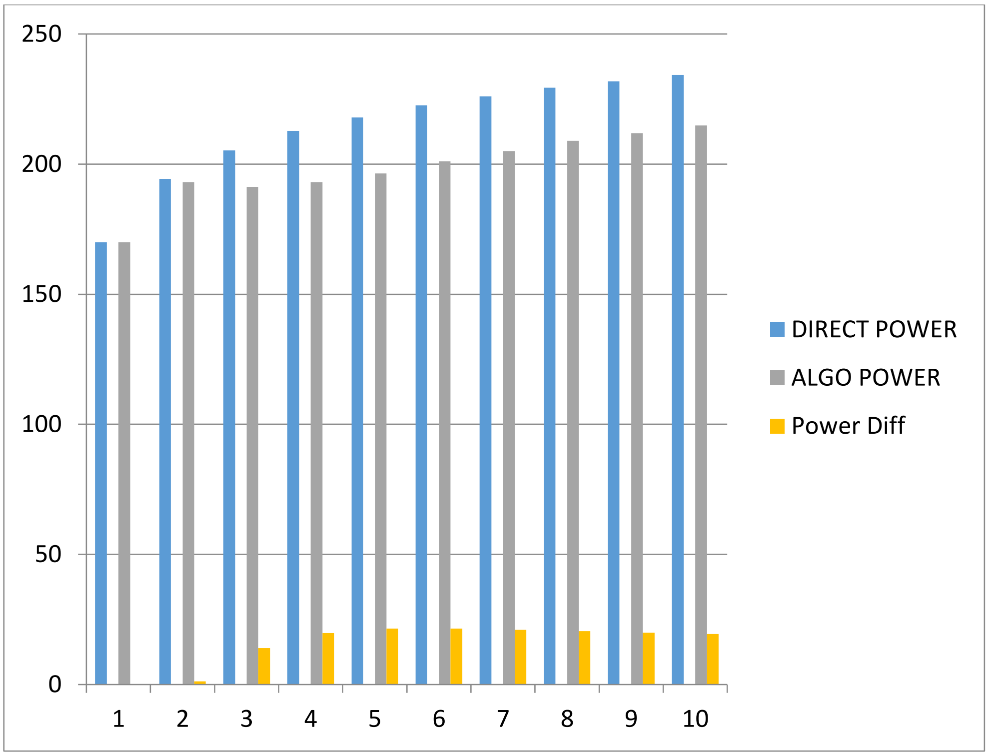

Fig. 4. *Power data collections with their differences*

From the table and chart above, ALOGO LINK has helped in saving power.

CONCLUSIONS

Power deployed by a user equipment to reach the base station poses as an environmental hazard and needs to be controlled. The lesser the power deployed for communication, the better the system and the safer the environment. Considering our results, our algorithm that used the relay scenario was found very useful for reducing transmission power by 21.5175dB which is a 10% decrement relative to the direct link in terms of the power deployed from a user equipment to a WiMAX base station at no extra cost to the operator; just a change in the algorithm in which they operate.

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УДК 621.396.1

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Повышение качества обслуживания в сетях WiMAX с использованием ретрансляционных узлов

Аннотация. В сетях WiMAX, используется две распространенных основных формы моделей. Это распространение в зоне не прямой видимости (2 ГГц до 11ГГц) и распространение в зоне прямой видимости (2 ГГц до 11ГГц). В будущем, операторам WiMAX нужно будет увеличить количество базовых станций в целях решения проблем, связанных с каналами в зоне не прямой видимости. Для того, чтобы обеспечить оперативное и экономически выгодное развертывания сетей WiMAX, будет применяться технология ретрансляции, которая не требует магистральных сетей. Статья представляет методы улучшения качества обслуживания на основе регулировки мощности, направленной на снижение энергопотребления и улучшения экологической обстановки. Выполнен анализ и проведено сравнение с целью оценки мощности, необходимой для установления прямой линии связи (то есть, соединения абонентского оборудования с базовой станцией собственной сети) и ретранслированной линии связи (то есть, использование внешней базовой станции сторонней сети в качестве ретрансляционной точки для связи с базовой станцией собственной сети). Параметром такой оценки является расстояние между абонентским оборудованием и базовыми станциями. В результате исследования разработан алгоритм выбора наилучшего маршрута соединения с учетом вариации расстояний между пользователем и базовыми станциями - собственной и сторонней сети. В выводах, предложенный метод ретрансляции, дал разницу в 21.5175dB по отношению к использованию прямой связи. Это 10% снижение мощности по отношению к прямой связи.

Ключевые слова: WiMAX; ретрансляционный узел; мощность; качество обслуживания; распределение Рэлея; внешняя базовая станция сторонней сети; базовая станция собственной сети.

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