Global Access to the Internet for All
Internet-Draft
Intended status: Informational
Expires: December 20, 2014

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Community Networks. Definition and taxonomy
draft-manyfolks-gaia-community-networks-00

Abstract

Several communities have developed initiatives to build large scale, self-organized and decentralized community wireless networks that use wireless technologies (including long distance) due to the reduced cost of using the unlicensed spectrum. This can be motivated by different causes: Sometimes the reluctance, or the impossibility, of network operators to provide wired and cellular infrastructures to rural/remote areas has motivated the rise of these networks. Some other times, they are built as a complement and an alternative to wired Internet access.

These community wireless networks have self sustainable business models that provide more localised communication services as well as providing Internet backhaul support through peering agreements with traditional network operators who see such community led networks as a way to extend their reach to rural/remote areas at lower cost.

This document defines these networks, summarizes their technological characteristics and classifies them, also talking about their socio-economic sustainability models.

There exist other networks, also based on sharing wireless resources of the users, but not built upon the initiative of the users themselves, nor owned by them. The characterization of these networks is not the objective of this document.

Status of This Memo

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1. Introduction

Several communities have developed initiatives to build large scale, self-organized and decentralized community wireless networks that use wireless technology (including long distance) due to the reduced cost of using the unlicensed spectrum. This can be motivated by different causes: Sometimes the reluctance, or the impossibility, of network operators to provide wired and cellular infrastructures to rural/ remote areas has motivated the rise of these networks [Pietrosemoli]. Some other times, they are built as a complement and an alternative to wired Internet access.

These community wireless networks have self sustainable business models that provide more localised communication services as well as providing Internet backhaul support through peering agreements with traditional network operators who see such community led networks as a way to extend their reach to rural/remote areas at lower cost.

A Community Network MAY or MAY NOT be organized as a company, but in any case this document only considers those operated and owned by the community members (e.g. as a cooperative). The fact of setting up a company is sometimes an advantage: it not only permits the provision of the service within the current regulatory framework (in some countries, in order to charge for the services, even in a cost-recovery mode only, you need to have a licence), but it also allows

to obtain wholesale prices from other operators when peering, which are way cheaper than those offered for normal clients, prices which influence greatly on the uptake of the service and in the financial sustainability of the Community Network.

There exist other networks, also based on sharing wireless resources of the users, but not built upon the initiative of the users themselves, nor owned by them. The characterization of these networks is not the objective of this document.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

1.2. Definition

Community Networks are large-scale, distributed, self-managed networks which are built and organized in a decentralized and open manner. Community Networks start and grow organically, they are open to participation from everyone agreeing to an open peering agreement. Knowledge about building and maintaining the network and ownership of the network itself is decentralized and open. Hardware and software used in community networks CAN be very diverse, even inside one network. A Community Network CAN have both wired and wireless links. The network CAN be managed by multiple routing protocols or network topology management systems. The network CAN serve as a backhaul for providing a whole range of services and applications, from completely free to even commercial services.

1.3. Scenarios

Scenarios where CNs are interesting or have been deployed.

1.3.1. Developing countries

There is no definition for what a developing country represents that has been recognized internationally, but the term is generally used to describe a nation with a low level of material well-being. In this sense, one of the most commonly used classification is the one by the World Bank, who ranks countries according to their Gross National Income (GNI) per Capita: low income, middle income, and high income, being those falling within the low and middle income groups considered developing economies. Developing countries have been also defined as those which are in transition from traditional lifestyles towards the modern lifestyle which began in the Industrial Revolution. Additionally, the Human Development Index, which

considers not only the GNI but also life expectancy and education, has been proposed by the United Nations to rank countries according to the well-being of a country and not solely based on economic terms. These classifications are used to give strong signals to the international community to the need of special concessions in support of these countries, implying a correlation between development and increased well-being.

However, at the beginning of the 90's the debates about how to quantify development in a country were shaken by the appearance of Internet and mobile phones, which many authors consider the beginning of the Information Society. With the beginning of this Digital Revolution, defining development based on Industrial Society concepts started to be challenged, and links between digital development and its impact on human development started to flourish. The following dimensions are considered to be meaningful when measuring the digital development state of a country: infrastructures (availability and affordability); ICT sector (human capital and technological industry); digital literacy; legal and regulatory framework; and content and services. The lack or less extent of digital development in one or more of these dimensions is what has been referred as Digital Divide. This divide is a new vector of inequality which - as it happened during the Industrial Revolution - generates a lot of progress at the expense of creating a lot economic poverty and exclusion. The Digital Divide is considered to be a consequence of other socio-economic divides, while, at the same time, a reason for their rise.

In this context, the so-called developing countries, worried of being left behind of this incipient digital revolution, motivated the World Summit of the Information Society which aimed at achieving "a people-centred, inclusive and development-oriented Information Society, where everyone can create, access, utilize and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life" [WSIS], and called upon "governments, private sector, civil society and international organisations" to actively engage to accomplish it [WSIS].

Most efforts from governments and international organizations focused initially on improving and extending the existing infrastructure for not leaving their population behind. Universal Access and Service plans have taken different forms in different countries over the years, with very uneven success rates, but in most cases inadequate to the scale of the problem. Given its incapacity to solve the problem, some governments included Universal Service and Access obligations to mobile network operators when liberalizing the telecommunications market. In combination with the overwhelming and

unexpected uptake of mobile phones by poor people, this has mitigated the low access indicators existing in many developing countries at the beginning of the 90s [Rendon].

Although it is undeniable the contribution made by mobile network operators in decreasing the access gap, its model presents some constraints that limits the development outcomes that increased connectivity promises to bring. Prices, tailored for the more affluent part of the population, remain unaffordable to many, who invest large percentages of their disposable income in communications. Additionally, the cost of prepaid packages, the only option available for the informal economies existing throughout developing countries, is high compared with the rate longer-term subscribers pay.

The consolidation of many Community Networks in high income countries sets a precedent for civil society members from the so-called developing countries to become more active in the search for alternatives to provide themselves with affordable access. Furthermore, Community Networks could contribute to other dimensions of the digital development like increased human capital and the creation of contents and services targeting the locality of each network.

1.3.2. Rural areas

The Digital Divide presented in the previous section is not only present between countries, but within them too. This is specially the case for rural inhabitants, which represents approximately 55% of the World's population, from which 78% inhabit in developing countries. Although it is impossible to generalize among them, there exist some common features that have determined the availability of ICT infrastructure in these regions. The disposable income of their dwellers is lower than those inhabiting urban areas, with many surviving on a subsistence economy. Many of them are located in geographies difficult to access and exposed to extreme weather conditions. This has resulted in the almost complete lack of electrical infrastructure. This context, together with their low population density, discourages telecommunications operators to provide similar services to those provided to urban dwellers, since they do not deemed them profitable

The cost of the wireless infrastructure required to set up a Community Network, including powering them via solar energy, is within the range of availability if not of individuals at least of entire communities. The social capital existing in these areas can allow for Community Network set-ups where a reduced number of nodes may cover communities whose dwellers share the cost of the

infrastructure and the gateway and access it via inexpensive wireless devices. In this case, the lack of awareness and confidence of rural communities to embark themselves in such tasks can become major barriers to their deployment. Scarce technical skills in these regions have been also pointed as a challenge for their success, but the proliferation of urban Community Networks, where scarcity of spectrum, scale, and heterogeneity of devices pose tremendous challenges to their stability and to that of the services they aim to provide, has fuelled the creation of robust low-cost low-consumption low-complexity off-the-self wireless devices which make much easier the deployment and maintenance of these alternative infrastructures in rural areas.

2. Technologies employed

These networks employ different technologies [WNDW]. They can be classified according to different criteria:

2.1. Antennas

Three kinds of antennas are suitable to be used in community networks: omnidirectional, directional and high gain antennas.

For local access, omnidirectional antennas are the most useful, since they provide the same coverage in all directions of the plane in which they are located. Above and below this plane, the received signal will diminish, so the maximum benefits are obtained when the client is at approximately the same height as the Access Point.

When using an omnidirectional antenna outdoors to provide connectivity to a large area, people often select high gain antennas located at the highest structure available to extend the coverage. In many cases this is counterproductive, since a high gain omnidirectional antenna will have a very narrow beamwidth in the vertical plane, meaning that clients that are below the plane of the antenna will receive a very weak signal (and by the reciprocity property of all antennas, the omni will also receive a feeble signal from the client). So a moderate gain omnidirectional of about 8 to 10 dBi is normally preferable. Higher gain omnis antennas are only advisable when the farthest way client are roughly in the same plane.

For indoor clients, omnis are generally fine, because the numerous reflections normally found in indoor environments negate the advantage of using directive antennas.

For outdoor clients, directive antennas can be quite useful to extend coverage to an Access Point fitted with an omni.

When building point to point links, the highest gain antennas are the best choice, since their narrow beamwidth mitigates interference from other users and can provide the longest links [Flickenger] [Zennaro].

24 to 34 dBi antennas are commercially available at both the unlicensed 2.4 GHz and 5 GHz bands, and even higher gain antennas can be found in the newer unlicensed bands at 17 GHz and 24 GHz.

Despite the fact that the free space loss is directly proportional to the square of the frequency, it is normally advisable to use higher frequencies for point to point links when there is a clear line of sight, because it is frequently easier to get higher gain antennas at 5 GHz. Deploying high gain antennas at both ends will more than compensate for the additional free space loss. Furthermore, higher frequencies can make due with lower altitude antenna placement since the Fresnel zone is inversely proportional to the square root of the frequency.

On the contrary, lower frequencies offer advantages when the line of sight is blocked because they can leverage diffraction to reach the intended receiver.

It is common to find dual radio Access Points, at two different frequency bands. One way of benefiting from this arrangement is to attach a directional antenna to the high frequency radio for connection to the backbone and an omni to the lower frequency to provide local access.

Of course, in the case of mesh networking, where the antenna should connect to several other nodes, it is better to use omnidirectional antennas.

Keep also in mind that the same type of polarisation must be used at both ends of any radio link. For point to point links, some vendor use two radios operating at the same frequency but with orthogonal polarisations, thus doubling the achievable throughput, and also offering added protection to multipath and other transmission impairments.

2.2. Link length

For short distance transmission, there is no strict requirement of line of sight between the transmitter and the receiver, and multipath can guarantee communication despite the existence of obstacles in the direct path.

For longer distances, the first requirement is the existence of an unobstructed line of sight between the transmitter and the receiver.

For very long path the earth curvature is an obstacle that must be cleared, but the trajectory of the radio beam is not strictly a straight line due to the bending of the rays as a consequence of non-uniformities of the atmosphere. Most of the time this bending will mean that the radio horizon extends further than the optical horizon.

Another factor to be considered is that radio waves occuppy a volume around the optical line, which must be unencumbered from obstacles for the maximum signal to be captured at the receiver. This volume is known as the Fresnel ellipsoid and its size grows with the distance between the end points and with the wavelength of the signal, which in turn is inversely proportional to the frequency.

So, for optimum signal reception the end points must be high enough to clear any obstacle in the path and leave extra "elbow room" for the Fresnel zone. This can be achieved by using suitable masts at either end, or by taking advantage of existing structures or hills.

Once a clear radio-electric line of sight (including the Fresnel zone clearance) is obtained, one must ascertain that the received power is well above the sensitivity of the receiver, by what is known as the link margin. The greater the link margin, the more reliable the link. For mission critical applications 20 dB margin is suggested, but for non critical ones 10 dB might suffice.

Bear in mind that the sensitivity of the receiver decreases with the transmission speed, so more power is needed at greater transmission speeds.

The received power is determined by the transmitted power, the gain of the transmitting and receiving antennas and the propagation loss.

The propagation loss is the sum of the free space loss (proportional to the square of the the frequency and the square of the distance), plus additional factors like attenuation in the atmosphere by gases or meteorological effects (which are strongly frequency dependent), multipath and diffraction losses.

Multipath is more pronounced in trajectories over water, if they cannot be avoided special countermeasures should be taken.

So to achieve a given link margin (also called fade margin), one can:

a) increase the output power.The maximum transmitted power is specified by the country's regulation, and for unlicensed frequencies is much lower than for licensed frequencies.

b) Increase the antenna gain. There is no limit in the gain of the receiving antenna, but high gain antennas are bulkier, present more wind resistance and require sturdy mounts to comply with tighter alignment requirements. The transmitter antenna gain is also regulated and can be different for point to point as for point to multipoint links. Many countries impose a limit in the combination of transmitted power and antenna gain, the EIRP (Equivalent Isotropically Irradiated Power) which can be different for point to point or point to multipoint links.

c) Reduce the propagation loss, by using a more favourable frequency or a shorter path.

d) Use a more sensitive receiver. Receiver sensitivity can be improved by using better circuits, but it is ultimately limited by the thermal noise, which is proportional to temperature and bandwidth. So one can increase the sensitivity by using a smaller receiving bandwidth, or by settling to lower throughput even in the same receiver bandwidth. This step is often done automatically in many protocols, in which the transmission speed can be reduced say from 150 Mbit/s to 6 Mbit/s if the receiver power is not enough to sustain the maximum throughput.

A completely different limiting factor is related with the medium access protocol. WiFi was designed for short distance, and the transmitter expects the reception of an acknowledgment for each transmitted packet in a certain amount of time, if the waiting time is exceeded, the packet is retransmitted. This will reduce significantly the throughput at long distance, so for long distance application it is better to use a different medium access technique, in which the receiver does not wait for an acknowledge of the transited packet. This strategy of TDMA (Time Domain Multiple Access) has been adopted by many equipment vendors who offer proprietary protocols alongside the standard WiFi in order to increase the throughput at longer distances. Low cost equipment using TDMA can offer high throughput at distances over 100 kilometres.

2.3. Layer 2

2.3.1. The 802.11 standard

Wireless standards ensure interoperability and usability by those who design, deploy and manage wireless networks. The Standards used in the vast majority of Community Networks come from the IEEE Standard Association's IEEE 802 Working Group.

The standard we are most interested in is 802.11 a/b/g/n, as it defines the protocol for Wireless LAN. Different 802.11 amendments have been released, as shown in the table below, also including their frequencies and approximate ranges.

802.11 prot	Release date	Freq (GHz)	BWdth (MHz)	Data Rate per stream (Mbit/s)	Approx range (m) indoor	outdoor
a	Sep 1999	5	20	6,9,12, 18, 24, 36, 48, 54	35	120
b	Sep 1999	2.4	20	1, 2, 5.5, 11	35	140
g	Jun 2003	2.4	20	6,9,12, 18, 24, 36, 48, 54	38	140
n	Oct 2009	2.4/5	20	7.2, 14.4, 21.7 28.9, 43.3, 57.8, 65, 72.2	70	250
n	Oct 2009	2.4/5	40	15, 30, 45, 60, 90, 120, 135, 150	70	250
ac	Nov 2011	5	20	Up to 87.6		
ac	Nov 2011	5	40	Up to 200		
ac	Nov 2011	5	80	Up to 433.3		
ac	Nov 2011	5	160	Up to 866.7		

In 2012 IEEE issued the 802.11-2012 Standard that consolidates all the previous amendments. The document is freely downloadable from IEEE standards [IEEE].

2.3.2. Deployment planning for 802.11 wireless networks

Before packets can be forwarded and routed to the Internet, layers one (the physical) and two (the data link) need to be connected. Without link local connectivity, network nodes cannot talk to each other and route packets.

To provide physical connectivity, wireless network devices must operate in the same part of the radio spectrum. This is means that 802.11a radios will talk to 802.11a radios at around 5 GHz, and 802.11b/g radios will talk to other 802.11b/g radios at around 2.4 GHz. But an 802.11a device cannot interoperate with an 802.11b/g device, since they use completely different parts of the electromagnetic spectrum. More specifically, wireless interfaces must agree on a common channel. If one 802.11b radio card is set to channel 2 while another is set to channel 11, then the radios cannot communicate with each other.

When two wireless interfaces are configured to use the same protocol on the same radio channel, then they are ready to negotiate data link layer connectivity. Each 802.11a/b/g device can operate in one of four possible modes:

1.Master mode (also called AP or infrastructure mode) is used to create a service that looks like a traditional access point. The wireless interface creates a network with a specified name (called the SSID) and channel, and offers network services on it. While in master mode, wireless interfaces manage all communications related to the network (authenticating wireless clients, handling channel contention, repeating packets, etc.) Wireless interfaces in master mode can only communicate with interfaces that are associated with them in managed mode.

2.Managed mode is sometimes also referred to as client mode. Wireless interfaces in managed mode will join a network created by a master, and will automatically change their channel to match it. They then present any necessary credentials to the master, and if those credentials are accepted, they are said to be associated with the master. Managed mode interfaces do not communicate with each other directly, and will only communicate with an associated master.

3.Ad-hoc mode creates a multipoint-to-multipoint network where there is no single master node or AP. In ad-hoc mode, each wireless interface communicates directly with its neighbours. Nodes must be in range of each other to communicate, and must agree on a network name and channel. Ad-hoc mode is often also called Mesh Networking.

4.Monitor mode is used by some tools (such as Kismet) to passively listen to all radio traHc on a given channel. When in monitor mode, wireless interfaces transmit no data. This is useful for analysing problems on a wireless link or observing spectrum usage in the local area. Monitor mode is not used for normal communications.

When implementing a point-to-point or point-to-multipoint link, one radio will typically operate in master mode, while the other(s) operate in managed mode. In a multipoint-to-multipoint mesh, the radios all operate in ad-hoc mode so that they can communicate with each other directly. Remember that managed mode clients cannot communicate with each other directly, so it is likely that you will want to run a high repeater site in master or ad-hoc mode. Ad-hoc is more flexible but has a number of performance issues as compared to using the master / managed modes.

2.3.3. 802.11af (TVWS)

Some Community Networks make use of TV White Spaces, using 802.11af standard.

2.3.4. Other options

802.11 is not the only layer 2 option to be used in Community Networks.

2.4. Layer 3

2.4.1. IP addressing

Most known Community Networks started in or around the year 2000. IPv6 was fully specified by then, but most almost all Community Networks still use IPv4. A community networks survey [Avonts] indicated that IPv6 rollout forms a challenge to Community Networks.

Most Community Networks use private IPv4 address ranges, as defined by RFC 1918 [RFC1918]. The motivation for this was the lower cost and the simplified IP allocation because of the large available address ranges.

2.4.2. Routing protocols

Community Networks are composed of possibly different layer 2 devices, resulting in a mesh of Community Network nodes. Connection between different nodes is not guaranteed, the link stability can vary strongly over time. To tackle this, some Community Networks use mesh network routing protocols while other networks use more traditional routing protocols. Some networks operate multiple routing protocols in parallel. E.g., they use a mesh protocol inside different islands and use traditional routing protocols to connect islands.

2.4.2.1. Traditional routing protocols

The BGP protocol, as defined by RFC 4271 [RFC4271] is used by a number of Community Networks, because of its well-studied behavior and scalability.

For similar reasons, smaller Community Networks opt to run the OSPF protocol, as defined by RFC 2328 [RFC2328].

2.4.2.2. Mesh routing protocols

A large number of Community Networks use the OLSR routing protocol as defined in RFC 3626 [RFC3626]. The pro-active link state routing protocol is a good match with Community Networks because it has good performance in mesh networks where nodes have multiple interfaces.

The Better Approach To Mobile Adhoc Networking (B.A.T.M.A.N.) [Abolhasan]protocol was developed by member of the Freifunk community. The protocol handles all routing at layer 2, creating one bridged network.

Parallel to BGP, some networks also run the BMX6 protocol [Neumann]. This is an advanced version of the BATMAN protocol which is based on IPv6 and tries to exploit the social structure of Community Networks.

2.5. Upper layers

From crowd shared perspective, and considering just regular TCP connections during the critical sharing time, the Access Point offering the CN service is likely to be the bottleneck of the connection. This is the main concern of sharers, having several implications. There should be an adequate Active Queue Management (AQM) mechanism that implement a Less than Best Effort policy for the CN user and protect the sharer. Achieving LBE behaviour requieres the appropriate tuning of the well known mechanisms such as ECN, or RED, or others more recent AQM mechanisms such as CoDel and PIE that aid on keeping low latency RFC 6297 [RFC6297].

The CN user traffic should not interfere with the sharers traffic. However, other bottlenecks besides client's access bottleneck may not be controlled by previously mentioned protocols. And so, recently proposed transport protocols like LETBAT [reference required] with the purpose of transporting scavenger traffic may be a solution. LEDBAT requieres the cooperation of both the client and the server to achieve certain target delay, therefore controlling the impact of the CN user all along the path.

There are applications that manage aspects of CN from the sharer side and from the client side. From sharer's side, there are applications to centralise the management of the APs conforming the CN that have been recently proposed by means of SDN [Sathiaseelan_a] [Suresh]. There are also other proposals such as Wi2Me [Lampropulos] that manage the connection to several CNs from the client's side. This application have shown to improve the client performance compared to a single-CN client.

On the other hand, transport protocols inside a multiple hop wireless mesh network are likely to suffer performance degradation for multiple reasons, e.g., hidden terminal problem, unnecessary delays on the TCP ACK clocking that decrease the throughout or route changing [Hanbali]. So, there are some options for network configuration. The implementation of an easy-to-adopt solution for TCP over mesh networks may be implemented from two different perspectives. One way is to use a TCP-proxy to transparently deal with the different impairments RFC 3135 [RFC3135]. Another way is to adopt end-to-end solutions for monitoring the connection delay so that the receiver adapts the TCP reception window (rwnd) [Castignani_c]. Similarly, the ACK Congestion Control (ACKCC) mechanism RFC 5690 [RFC5690] could deal with TCP-ACK clocking impairments due to inappropriate delay on ACK packets. ACKCC compensates in an end-to-end fashion the throughput degradation due to the effect of media contention as well as the unfairness experienced by multiple uplink TCP flows in a congested WiFi access.

2.5.1. Services provided by these networks

This section provides an explaining of the services between hosts inside the CN. They can be divided into Intranet services, connecting hosts between them, and Internet services, connecting to nodes outside the network.

2.5.1.1. Intranet services

- VoIP (e.g. with SIP)

- remote desktop (e.g. using my computer and my Internet connection when I am on holidays in a village).

- FTP file sharing (e.g. distribution of Linux software).

- P2P file sharing.

- public video cameras.

- DNS.

- online games servers.

- jabber instant messaging.

- IRC chat.

- weather stations.

- NTP.

- Network monitoring.

- videoconferencing / streaming.

- Radio streaming.

2.5.1.2. Access to the Internet

2.5.1.2.1. Web browsing proxies

A number of federated proxies provide web browsing service for the users. Other services (file sharing, skype, etc.) are not usually allowed.

2.5.1.2.2. Use of VPNs

Some "micro-ISPs" may use the CN as a backhaul for providing Internet access, setting up VPNs from the client to a machine with Internet access.

3. Topology

These networks follow different topology patterns, as studied in [Vega].

Regularly rural areas in CNs are connected through long-distance links (the so-called community mesh approach) which in turn convey the Internet connection to relevant organisations or institutions. In contrast, in urban areas, users tend to share and require mobile access. Since these areas are also likely to be covered by commercial ISPs, the provision of wireless access by Virtual Operators like FON is the way to extend the user capacity (or gain connection) to the network. Other proposals like Virtual Public Networks [Sathiaseelan_a] can also extend the service.

As in the case of main Internet Service Providers in France, Community Networks for urban areas are conceived as a set of APs sharing a common SSID among the clients favouring the nomadic access. For CNs users in France, ISPs promise to cause a little impact on their service agreement when the CN service is activated on clients' APs. Nowadays, millions of APs are deployed around the country performing services of nomadism and 3G offloading, however as some studies demonstrate, at peatonal speed, there is a fair chance of performing file transfers [Castignani_a] [Castignani_b]. In studied scenarios in France and Luxembourg the density of APs around the urban areas (mainly in downtown and residential areas) there is a

crowded deployment of APs for the different ISPs. Moreover, performed studies reveal that aggregating available networks can be beneficial to the client by using an application that manage the best connection among the different CNs. For improving the scanning process (or topology recognition), which consumes the 90% of the connection/reconnection process to the Community Network, the client may implement several techniques for selecting the best AP [Castignani_c].

4. Classification

This section classifies Community Networks according to their intended usage. Each of them have different incentive structures, maybe common technological challenges but most importantly interesting usage challenges which feeds into the incentives as well as technological challenges

Some networks exist, which they are outside the scope of the present document. A first example are the networks created and managed by City Councils (e.g., [Heer]).Some companies [FON reference missing] develop and sell Wi-Fi routers with a dual access: a Wi-Fi network for the user, and a shared one. A user community is created, an people can join it different ways: they can buy a dual router, so they share their connection and in turn they get access to all the routers associated to the community. Some users can even get some revenues every time another user connects to their Wi-Fi spot. Other users can just buy some passes in order to use the network. Some telecommunications operators can collaborate with the community, including in their routers the possibility of creating these two networks.

4.1. Community led Wireless Mesh, led by the people

These networks grow organically, since they are formed by the aggregation of nodes belonging to different users. A minimum governance infrastructure is required in order to coordinate IP addressing, routing, etc. A clear example of this kind of Community Network is described in [Braem].

4.2. Crowdshared approaches, led by the people and third party stakeholders

These networks follow the next approach: the home router creates two wireless networks, one of them to be normally used by the owner, and the other one is public. A small fraction of the bandwidth is allocated to the public network (as e.g. Less-than-best-effort or scavenger traffic), to be employed by any user of the service in the immediate area. An example is described in [PAWS].

A Virtual Private Network (VPN) is created for public traffic, so it is completely secure and separated from the owner's connection. The network capacity shared may employ a less-than-best-effort approach, so as not to harm the traffic of the owner of the connection [Sathiaseelan_a].

There are three actors in the scenario:

- End users who sign up for the service and share their network capacity. As a counterpart, they can access anyone's home broadband for free.

- Virtual Network Operators (VNOs) are stakeholders with socio-environmental objectives. They can be a local government, grass root user communities, charities, or even content operators, smart grid operators, etc. They are the ones who actually run the service.

- Network operators, who have a financial incentive to lease out the unused capacity [Sathiaseelan_b] at lower cost to the VNOs.

VNOs pay the sharers and the network operators, thus creating an incentive structure for all the actors: the end users get money for sharing their network, the network operators are paid by the VNOs, who in turn accomplish their socio-environmental role.

4.3. Testbed

In some cases, the initiative to start the network is not from the community, but from a research entity (e.g., a university), with the aim of using it for research purposes [Samanta].

5. Acknowledgements

6. IANA Considerations

This memo includes no request to IANA.

7. Security Considerations

No security issues have been identified for this document.

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