TECHNOLOGY WHITE PAPER

High speed Internet in sparsely populated areas

Covering sparsely populated areas is not economically viable using conventional techniques. A solution combining satellite access shared between a number of users via WiFi links is a solution that offers wide-area coverage well suited to small villages. Also, this solution is economically effective. This article describes the performance characteristics of a deployment of this kind in terms of coverage and bit rate accessible to a user, and positions the pairing of WiFi with satellite technology versus other technologies such as ADSL, WIP or WiMax. The proposed solution appears well suited to covering isolated areas in economically viable conditions.

ALCATEL

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HIGH SPEED INTERNET IN SPARSELY POPULATED AREAS

Satellites in association with WiFi distribution provide a technically attractive and cost-effective solution for narrowing the digital divide.

Introduction

The increasing demand for broadband access is leading telecommunication operators to deploy more and more Asymmetric Digital Subscriber Lines (ADSL), providing high speed yet inexpensive access to Internet services. This technology is increasingly successful and is rapidly expanding in urban and suburban areas. However, there are technical and economic difficulties when deploying it in sparsely populated areas, often hundreds of miles away from the concentration centers (Digital Subscriber Line Access Multiplexers; DSLAM).

Beyond about 5 km, connecting isolated communities to ADSL using alternative technologies requires an investment that operators will only consider for a minimum number of subscribers (100, on average). With a penetration rate of approximately 25% and an average of 2.45 people per household, only villages with more than 1000 inhabitants will be connected. This means that between 10 and 30% of the population are left without broadband access, depending on the country.

Satellite technologies coupled with microwave distribution by WiFi network offer an alternative, cost-effective solution that can help to narrow this "digital divide". The solution is equally well suited to domestic, business areas and holiday resorts, like campsites and marinas, that could not hitherto be connected easily to the Internet Protocol (IP) network.

Deployment and Performance

WiFi technology, as defined by the Institute of Electrical and Electronic Engineers (IEEE) 802.11 a, b, and g standards and their updates, is available. In practice, a, b and g standard WiFi equipment, and even equipment combining a, b and g technologies, is widely available at low cost. Similarly, directional and sectorial antennas are available for the 2.4 GHz and 5 GHz WiFi standard frequency bands.

These technologies support the provision of DSL services to groups of users without the benefit of an adequate wireline infrastructure (for example, an isolated village with fewer than 1000 inhabitants). However, in some countries (in particular in France) the regulations do not permit 5 GHz 802.11a equipment to be deployed outdoors. Consequently, deployment must be tailored to the local regulatory constraints.

A typical deployment could be: a local authority installs WiFi access points equipped with sectorial antennas on a high point in the village (bell tower, public building, etc). These access points are then connected to the Internet via a high speed satellite network. Users deploy WiFi equipment with low directivity antennas, similar to satellite TV reception equipment. This deployment is

Fig. 1 Point-to-multipoint deployment

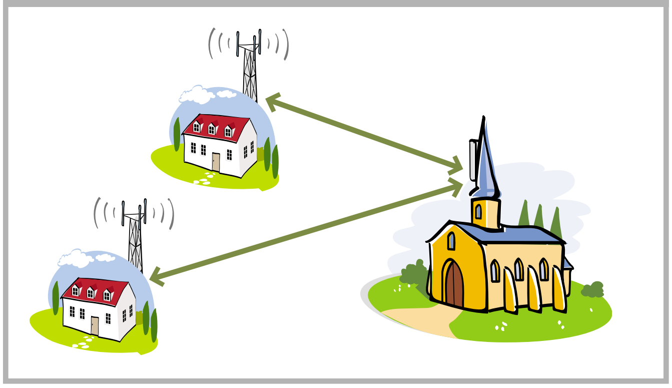
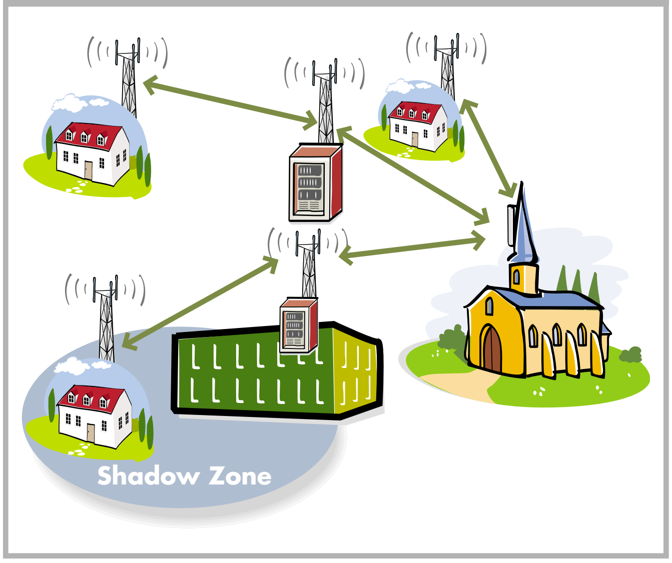


Fig. 2 Point-to-multipoint plus relay deployment to provide coverage in a shadow zone



illustrated in *Figure 1*. However, the coverage is highly dependent on how the antenna is installed: clear path between the user's antenna and the access point, surrounding obstacles, and so on.

Figure 2 shows a deployment for a shadow zone in which the use of relays provides good quality coverage.

The performances achievable by various deployment scenarios have been simulated. *Figures 3* and *4* show two examples of coverage performance (obtained by simulations) in different deployment conditions. *Figure 3* is for deployment in the village center: the users' antennas are installed on roofs and may be close to obstacles. *Figure 4* shows deployment in a fairly clear environment, with the line of sight between the access point and user equipment obstructed only by sparse vegetation.

The transmitted powers are the maxima allowed by the IEEE 802.11b standard and current regulations in France. User antennas are of the "Yagi" type (gain of 15 dBi). The coverage at 11 Mbit/s (802.11b) extends from 1.5 km in the center of the village to 4 km in a clearer environment, while coverage of the 54 Mbit/s mode (802.11g) varies from 400 m to 800 m. Additional simulations show that, depending on deployment conditions, the range of the 1 Mbit/s mode for 802.11b equipment can vary from 700 m to 7 km. However, in most cases the ranges obtained by simulation remain compatible with the coverage of a village.

The problem of shadow zones caused by ground irregularities can be overcome by deploying relays in appropriate locations (see *Figure 2*). Relays installed on a building obstructing the direct path between the user antenna and the access point antenna provide coverage for users in the shadow zone, minimizing the cost of deploying the infrastructure. This use of relays can also extend the main coverage and service to users at the edge of the village.

What quality of service can be expected from a deployment of this kind? To answer this question, the following heavy load scenario was considered: 70% of subscribers have Internet traffic, 5% receive video streams at 256 kbit/s and 25% send e-mails. Three levels of service penetration were studied: 20, 60 and 100 users.

Figure 5 shows the web throughput that subscribers can expect according to the satellite connection's downlinks and uplinks, while *Figure 6* gives the

Fig. 3 Deployment in a village center; the x-axis shows the distance to the satellite station in km

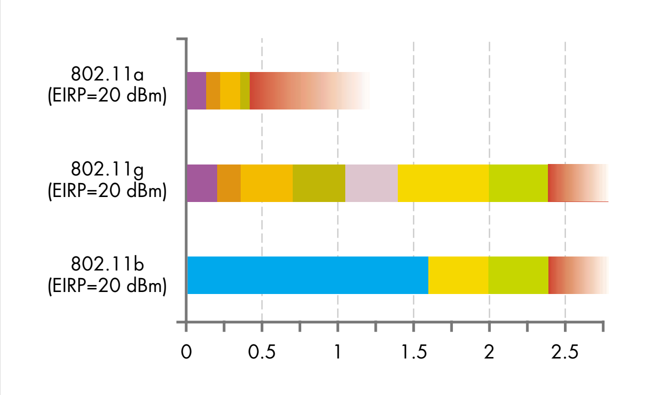


Fig. 4 Coverage in a fairly clear area with only sparse vegetation

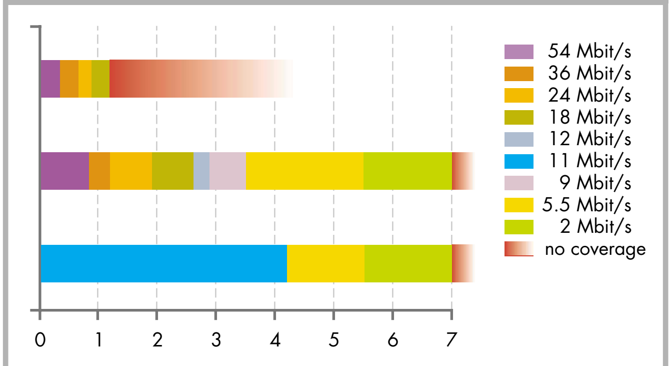


Fig. 5 Web throughput

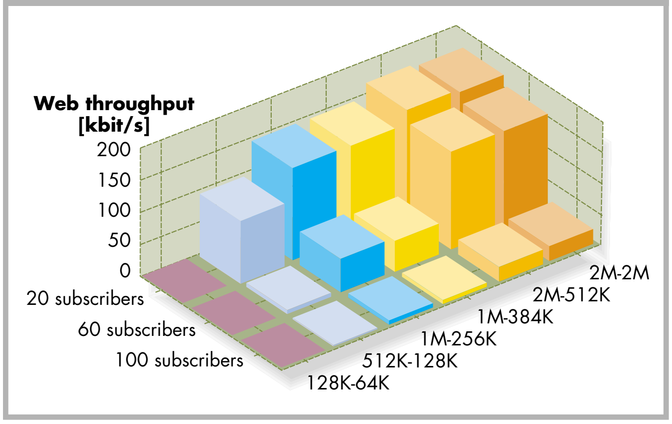
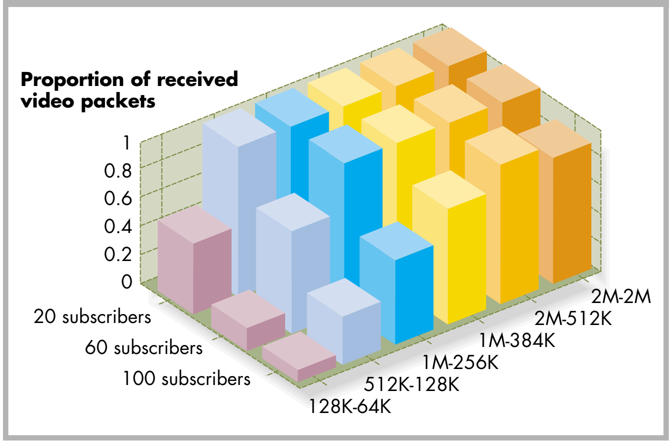


Fig. 6 Proportion of video packets received correctly



proportion of video packets correctly received. This proportion can be slightly less than "1" without the video quality being severely impaired.

In the case of 20 subscribers, a 1 Mbit/s satellite downlink and a 256 kbit/s uplink allow Internet users a rate of 140 kbit/s without video downloads being affected, whereas with 60 subscribers, a 2 Mbit/s / 512 kbit/s satellite configuration is needed. When there are 100 subscribers, the quality of the video streams becomes unacceptable.

Fig. 7 Serving a rural area

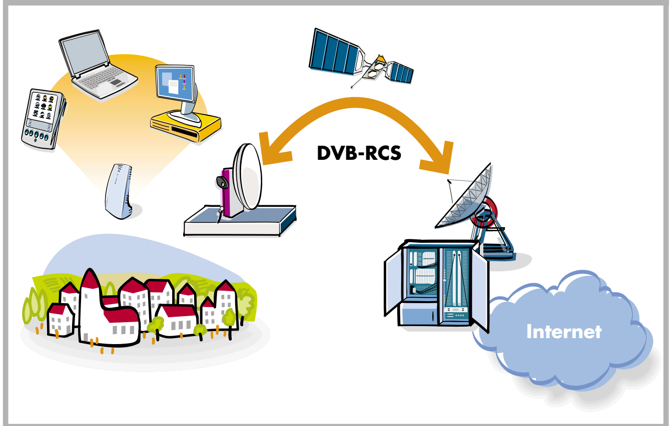
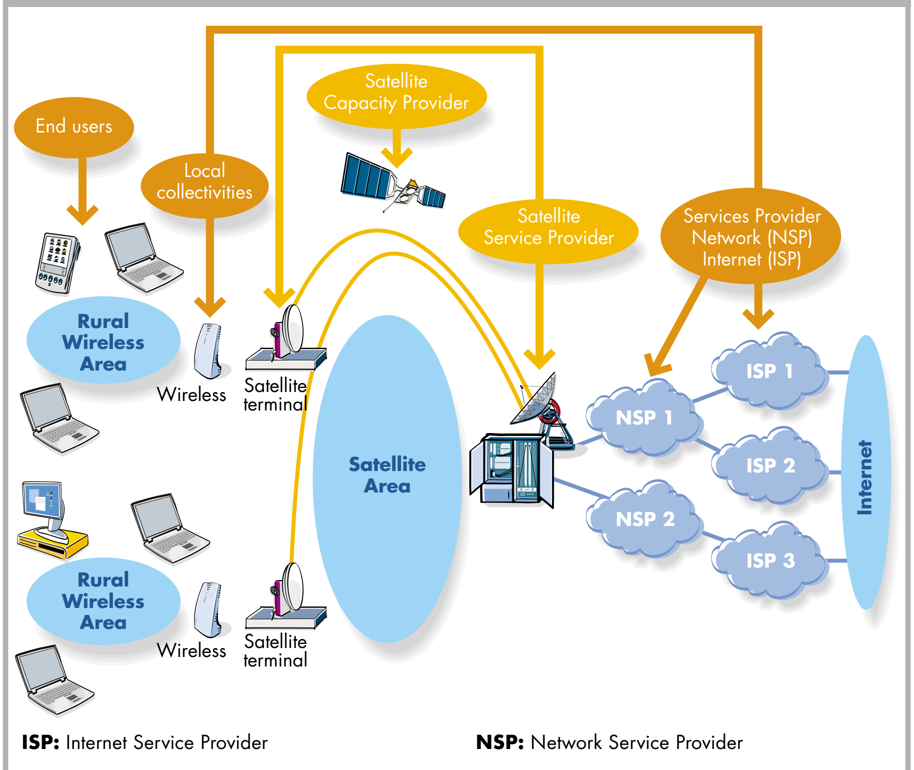


Fig. 8 Players and roles for the rural market



Alcatel Solution

Overview

The Alcatel solution, based on Digital Video Broadcast – Return Channel by Satellite (DVB-RCS) technology for satellite access, is illustrated in *Figures 7* and *8*. The solution is targeted at rural sites (villages) for sharing satellite access and hot-spots (hotels, industrial areas, campsites, shopping malls, etc) that cannot be connected to the broadband network.

The Alcatel solution comprises the following elements:

- Connection station, which is the interface between the various terrestrial networks and the satellite terminals via a transparent satellite (not described here), the capacity of which is leased from a satellite operator like Eutelsat or SES Astra in Europe, Asiasat in Asia-Pacific, SES Americom or Telesat in America. This connection station includes elements to format and transmit the IP packets to the satellite, elements to receive and extract the IP packets from the satellite, management elements and the Broadband Access Server (BAS) interface with the terrestrial networks.
- At the other end of the satellite chain is a satellite terminal consisting of an outdoor part, comprising the antenna of around 1 m diameter and the electronic components, and an indoor part, comprising the modem and router. The satellite terminal is linked to a WiFi access point via either the satellite terminal's 10/100 BT network interface or a router.

Signals from the station to the terminals use the Ku band (12 to 14 GHz), while signals from the terminals to the station use the Ku or Ka band, depending on the system. In its current version, the DVB-RCS system offers an overall downstream bitrate of up to 45 Mbit/s for a total bandwidth of 36 MHz, and return bitrates of up to 2 Mbit/s per terminal, with return access in multi-carrier mode. Future versions should at least double the downstream rate while rationalizing the resource through adaptive modulation and encoding techniques.

In the case of rural access, the access point is linked to an outdoor omnidirectional or sectorial (with one or more sectors depending on the topology) antenna installed at a high point. The antenna has a gain of 10 to 15 dBi, or even more. The user terminals are also linked to an outdoor antenna for remote reception. This antenna will normally be directional and have a gain of 10 to 15 dBi, or more.

For a hot-spot, the access point is linked to an indoor antenna or outdoor antenna (on a campsite, for example) with an average gain. In this case, the user terminals are equipped with standard WiFi cards.

The system can be used to offer the following services:

- Internet and e-mail,
- file transfer,
- audio and video streaming,
- multicast,
- secure end-to-end connections (Virtual Private Networks; VPN) for access to enterprise networks.

From the management point of view, the system handles data encryption (Wireless Encryption Protocol; WEP), authentication by a Remote Authentication Dial-In User Service (RADIUS) server, subscriber management and billing, and remote or local management of the base stations.

The players

There are a number of possible models. *Figure 8* shows an example of the various players in the case of rural distribution.

- End user who has a PC or Personal Digital Assistant (PDA) connected to WiFi subscriber equipment linked to an outdoor antenna.
- WiFi access provider; this might be a local community that manages one or more access points.
- Satellite access provider, which provides the satellite access system, connection station and terminals, and which guarantees the bandwidth of the satellite system.
- Network service provider, which provides access from the connection station to the backbone network.
- Internet service provider, which provides the subscriber with access to Internet services. This may be the same as the network service provider.

Markets and Alternative Technologies

The system offers a solution to the problem of narrowing the digital divide in rural areas. Since it enables WiFi coverage to be connected to the IP core network, it can also be used to connect several isolated hot-spots. Currently the alternative to a satellite connection is ADSL, but in a few years time we will be able to count on WiMax technology and its upgrades, both for connection and for subscriber access.

Figure 9 shows various connection technologies for the rural market, some involving satellite access techniques:

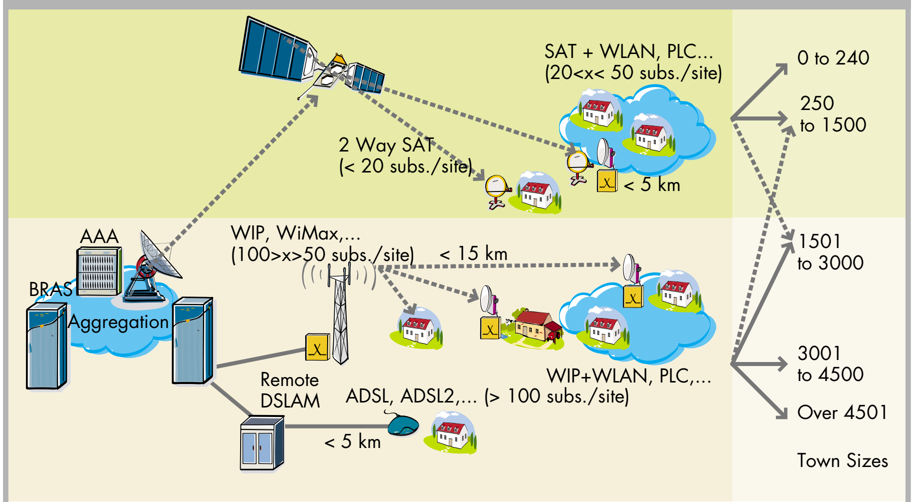
- The technology described in the article is ideal for between about 20 and 50 local subscribers, corresponding to a population of up to 1000 people. An alternative technology, called Power Line Communication (PLC), can also be used.
- A satellite in direct access mode is the typical solution for fewer than 20 subscribers. Competition between the two satellite access modes (direct and via an access link) is highly dependent on the price of the satellite terminal.

Wireless Internet Protocol (WIP) or WiMax terrestrial wireless access mode is of interest for between 50 and 100 subscribers over distances of around 15 km. ADSL access, with its extended mode (remote ADSL), is suitable for distances of up to 5 km and a minimum of a hundred subscribers per site.

Satellite systems can also be used in conjunction with ADSL (Micro DSLAM), allowing small villages to be linked through ADSL and satellite to broadband networks.

All these technologies are complementary; the right hand side of *Figure 9* shows the distribution of these technologies according to town size, with France as the example.

Fig. 9 Different access technologies



AAA: Authentication, Authorization and Accounting
BRAS: Broadband Remote Access Server
PLC: Power Line Communication
WLAN: Wireless Local Area Network

RASCOM project

This project, for which Alcatel is lead contractor, is designed to provide coverage of the entire African continent and a part of Europe and the Middle East between now and 2006. It is based on a satellite in geostationary orbit using the Ku and C bands. The ground networks associated with the satellite system will include earth stations and low cost rural terminals, fed by solar power.

The RASCOM system will offer the capabilities required to provide fixed voice and data links, Internet access and broadband radio broadcasting services to the entire African continent; it will ultimately enable almost 300 000 hitherto isolated villages to be connected.

Innovative transmission techniques specially developed for this project, and the benefits of economies of scale for the terminals, will enable communication services to be offered at very attractive prices, affordable by the local populations.

The project owes its name to the intergovernmental organization RASCOM (Regional African Satellite Communication Organization), which represents the interests of 44 African operators. RASCOM is therefore the manifestation of the will of African governments and telecommunication operators to pool their efforts to offer the continent an infrastructure based on space technology. This initiative is not only a global response to a set of identified needs, but is also characterized, more specifically, by the offer of inexpensive telecommunication services, thus giving substance to the desire to extend universal service in Africa.

Conclusion

The solution described for bringing isolated areas out of the wilderness shows that the coverage of a terrestrial station in a conventional DVB-RCS satellite network can be extended using WiFi technology. This coverage provides the same kind of service as currently offered by ADSL networks, with a similar access bit rate. The performance achieved will depend on the length of the satellite hops and on the multiplexing of multiple users over the WiFi link.

Economic analysis of this solution shows it to be well suited to villages with typically 100 to 1000 inhabitants. There are many such villages in Europe and in the rest of the world, so it can help significantly to reduce the digital divide. Potentially, around 10% of the population can be covered by this kind of solution fairly quickly.

Although the combination of satellite and WiFi is a good solution for villages and hot-spots, satellite systems can also be combined with other access networks, such as ADSL, to bring Internet access to isolated areas.

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Abbreviations

AAA Authentication, Authorization and Accounting
ADSL Asymmetric Digital Subscriber Line
BAS Broadband Access Server
BRAS Broadband Remote Access Server
DSL Digital Subscriber Line
DSLAM DSL Access Multiplexer
DVB-RCS Digital Video Broadcasting – Return Channel by Satellite
IEEE Institute of Electrical and Electronics Engineers
IP Internet Protocol
ISP Internet Service Provider
NSP Network Service Provider
PDA Personal Digital Assistant
PLC PowerLine Communication
RADIUS Remote Authentication Dial-In User Service
SAT Satellite
VPN Virtual Private Network
WEP Wireless Encryption Protocol
WiMAX Specification for interoperability with the IEEE 802.16a standard
WIP Wireless IP
WLAN Wireless Local Area Network