Next Generation Satellite Broadband for Enabling Universal Service Commitment

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ABSTRACT

Satellite broadband is considered one of the key technologies for high speed Internet service provision to remote areas. This paper presents results of a multi-disciplinary project that seeks to understand the requirements and socio-economic implications of using satellite for rural broadband deployment. Our analysis is used to formulate simulation models (application and traffic) that are then used to evaluate the performance of using a set of new QoS methods for a range of applications.

1. INTRODUCTION

Broadband connectivity has the potential to reduce the barrier of distance for those living and working rurally by connecting people with one another and providing access to a range of essential and desirable digital resources [1]. One UK plan was known as "Universal Service Commitment" (USC) with the goal to enable broadband access at 2Mbps for everyone in UK by 2012 [4]. The Royal Society of Edinburgh (RSE) also produced recommendations for universal access for Scotland with a target of 2015, and created the Digital Scotland Trust to oversee the digital health of the Scottish economy [5]. While much of this broadband infrastructure is envisaged to use fibre technology or a combination of fibre and copper, it is unlikely that the available public and private resources will be sufficient to enable all to upgrade to the super-fast speeds offered by these technologies. We therefore need to consider how and what should be done to supply broadband for the 'final third' [2] who cannot be reached using these technologies.

Where broadband access is available in rural locations, this is often poorer in terms of speed. In some places, it may be completely unavailable at an economic installation cost. This results in unequal broadband coverage that contributes to the 'digital divide', where different groups in society experience different levels of access to and adoption of digital technologies. The divide may place some rural people at a severe disadvantage relative to their urban counterparts, especially since high-speed broadband is crucial for rural businesses to enable innovation, wealth creation, and to enhance productivity and growth.

There are many reasons for the inequality in Internet access. The capacity (speed) of copper-line technologies, e.g. Digital Subscriber Line (DSL) between the local exchange and a customer, degrades with increasing distance to the exchange (Figure 1).

A common upgrade method, is to replace all or part of the copper cable with fibre optic cabling. Fibre To The Home, FTTH or Fibre To The Cabinet, FTTC, can provide super-fast broadband (Figure 2) for groups of users in a common location. FTTC is well-suited to urban environments, where many users are within reach of a single cabinet. The typically longer distances, incur a higher upgrade cost for rural users, therefore current funding envisages that this approach is not expected to become available for the final third (35-40% households). Most of these locations correspond to rural communities/homes [3].

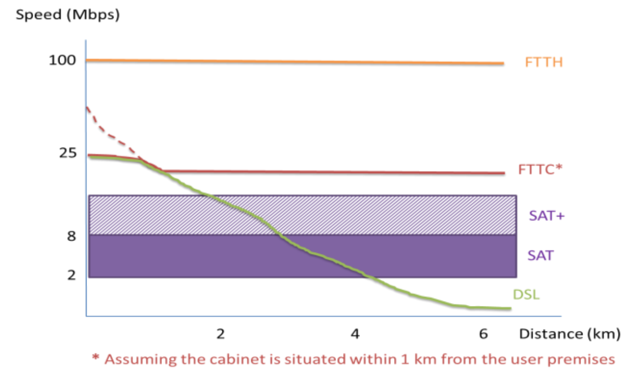

Figure 1: Typical broadband speed as a function of customer distance from the exchange; satellite can offer a range of speeds determined by the satellite network operator.

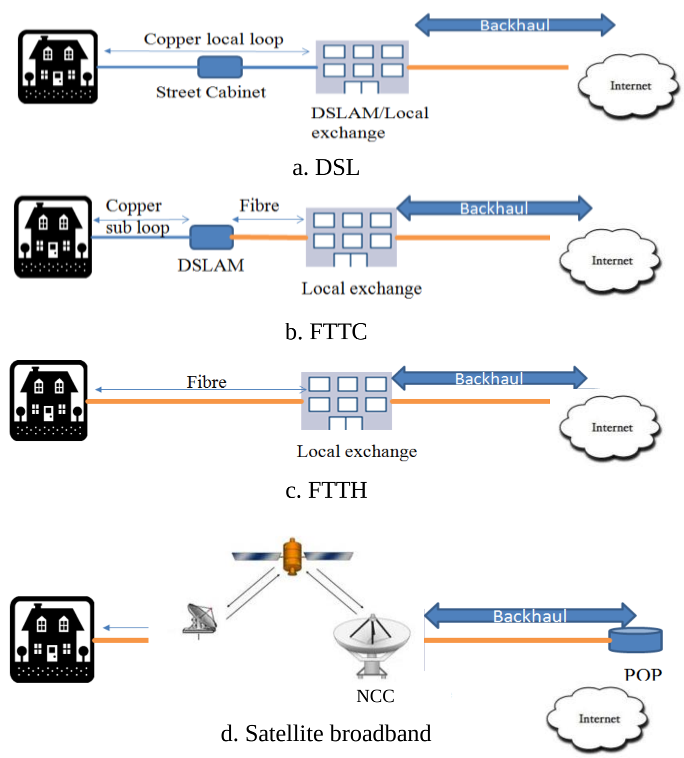

Figure 2: Broadband Access Technologies

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One of the key issues in providing broadband service relates with the costs of infrastructure installation and operation.

The deployment cost for fibre cables per metre is almost the same for DSL and FTTH, but can be prohibitive a long distance. The lower density of customers in a rural location can also increase the cost per-customer-per-Mbps. This may result in fewer users sharing exchange equipment and lower aggregated backhaul speed from a cabinet or from the exchange to the Internet Service Provider, usually reducing the maximum offered speed and resulting in a higher "contention ratio" for many rural users.

The drawbacks of cabled technologies require the final third to rely on a complementary technology for their broadband service. Wireless, e.g. long-distance Wi-Fi, WiMAX or cellular services (3G/4G) may be viable in some locations, but these also depend on investment in local infrastructure, and have a higher cost per consumer in places with a low population density where the installation and backhaul costs are shared by fewer customers.

Satellite broadband is another complimentary technology. This is well-suited to a rural location, since it can deliver high speed access anywhere over a large geographic area. The cost of deployment is therefore largely independent of the remoteness of users (except for the one-off costs needed for an installer to travel to a remote location). Recent advances in satellite technology have also significantly increased the available capacity to customers, resulting in significant reduction of the per-customer-per-Mbps cost.

In all access technologies, operational costs need to be shared between the set of users that share the access – for DSL, this is reflected in the contention ratio. In a satellite system, the sharing is different, with no backhaul and with the entire network of users sharing one or more satellite platforms. The much larger pool of satellite capacity and centralized control brings many possibilities for customization of the service supplied to a user. This reduces the planning needed for satellite ISPs to add users to the system, and provides greater flexibility than DSL (where customer contention must be considered) and can offer the possibility of dynamic variation of the Quality of Service (QoS) offered to a customer.

2. METHODOLOGY

Acceptance of an access technology depends on whether a customer feels they have appropriate performance for the applications they choose to use. There is an inevitable trade-off between the cost of providing the network capacity and the performance experienced. For example, the QoS design will impact the performance of web browsing, or Voice-over-IP (VoIP) quality. Most importantly, an appropriate design may be tailored to prevent degradation of the service when multiple customer applications simultaneously share access.

The remainder of this paper uses models to represent rural user traffic and demonstrates the trade-off between cost and performance with a focus on supporting multiple services and the appropriate choices for satellite access network design.

2.1 User Analysis

Requirements are being identified using a baseline studies of rural users engaged in the Creative Industries. Qualitative interviews are establishing patterns of use and the expectations of users who have not previously had access to broadband Internet services.

In parallel, experiments have profiled the performance of a satellite access terminal at the RCUK dot.rural Hub. This provided qualitative and quantitative analysis to build a real-world traffic model. This provided an input to the design of a simulator for a satellite access system and to explore engineering trade-offs.

In the next stage of research, a set of businesses will be supplied with satellite broadband. Their experience and acceptance of a range of services (with corresponding cost/performance tradeoffs) will be recorded. We expect evaluation in the remainder of the project to inform both the engineering and a study the socio-economic impact on rural businesses in terms of their sustainability and development *e.g.* in terms of engaging with a broader audience and distributing created digital content.

2.2 Technological Study

The technological study was based on an emerging broadband satellite access standard, DVB-RCS2 [6]. This was chosen because it is the only open next-generation multivendor standard for broadband access. We consider the conflicting goals required to satisfy user requirements/expectation, and focus on the trade-offs between efficiency (linked to operational cost) and application performance. The basic principles of operation and techniques of DVB-RCS2 are similar to those deployed in proprietary systems, such as Hughes IPoS [7], so we expect our results to also be applicable to other next generation satellite access technologies.

3. SIMULATION ANALYSIS

3.1 Experimental Setup

A typical satellite access system uses a high-speed Forward Link (FL). A Network Control Centre (NCC) coordinates sharing of the Return Link (RL) capacity between active terminals. Traffic arriving at a terminal is queued until the NCC allocates capacity for it to be sent on the RL. This allocation decision is informed by capacity requests sent by each terminal using the RL. Requests may be derived using a range of methods to estimate the required rate for the next interval. Rate-Based Dynamic Capacity (RBDC) measures the arrival rate of traffic, while Volume-Based Dynamic Capacity (VBDC) makes a request based on the amount of traffic queued in a terminal at a particular instant.

3.2 Web Performance

The design choices that may benefit particular applications (e.g. web in this case) need to be understood to get the best possible cost vs. performance. It is therefore useful to understand the range of services that can be made available. Web browsing and web-based access are often the primary Internet service for both home and business users. A simulator was therefore developed with a page-based model [8] to analyse the web performance for a rural satellite access and compare this with that offered in urban areas via DSL or Fibre.

Entry-level speeds offered by satellite operators are typically lower than superfast broadband (i.e. FTTC/FTTH). However, webpage download via satellite may be much faster than download using rural DSL.

To allow control of user performance, we introduce the concept of a Request Class (RC). An RC combines a set of capacity request methods in different proportion characterised by the percentage ($\boldsymbol{p}$) associated with each request method ($\boldsymbol{p}$ x RBDC + (1-$\boldsymbol{p}$) x VBDC). A series of experiments explore how the choice of the RC can affect webpage download time and resource allocation efficiency. Figure 3 shows that an appropriate selection can improve overall performance, e.g. using $\boldsymbol{p}$=0.2, a webpage download can be 10-15s faster than using VBDC and 5-8% more efficient than using only RBDC.

The cost v performance can therefore be controlled by a satellite network operator and can be tuned at the NCC. Most modern satellite equipment is already capable of higher speeds – hence the capacity of a satellite access terminal could be upgraded without needing to install new equipment and could be increased as demand grows. This is a contrast to DSL access, which usually require upgrades to the cable and installed equipment.

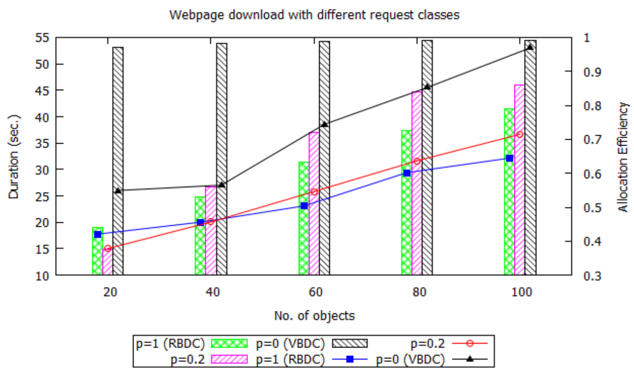

Figure 3: Webpage download time for a HTTP session with different Request Classes; a combination of RBDC and VBDC methods may provide acceptable performance and efficiency.

3.3 Performance for other Internet Traffic

An access technology must also support more complex combinations of traffic than offered by simple web browsing. This includes time-sensitive traffic to support telephony and other voice services. This section therefore describes how QoS methods may be used to design a service that can support a range of Voice over IP (VoIP) applications. This design is more complex, since real-time traffic is often more difficult to estimate.

A new predictive allocation strategy is proposed. Figure 4 illustrates the improvement in efficiency for a desired quality (Mean Opinion Score, MOS). The method shows a higher number of VoIP flows consume less resource due to better multiplexing. A policy can be tuned to either increase the number of concurrent users for a broadband service or to reduce operational costs by reducing excess capacity.

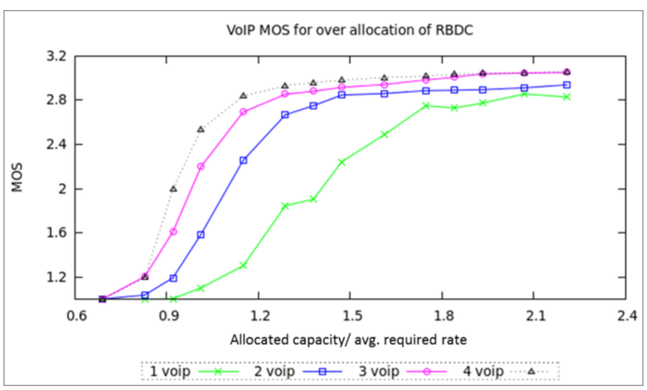

Figure 4: MOS for multiple VoIP sessions with a range of ratios for allocated capacity/average required rate; higher number of flows result in better multiplexing and require the allocation of less excess capacity.

Since a terminal is allowed to use multiple RCs, each can be associated with a different quality of service class (e.g. reflecting a specific application). These RCs may be customised for the traffic profiles if these become important to a user. This may offer a range of options for selecting the most suitable price plan.

In the future, a satellite system could benefit from the large shared capacity pool, introducing the possibility to dynamically upgrade performance of a user, when needed, by allocating currently unused capacity (e.g. SAT+ in Fig. 1) [9]. Any increase in the capacity assigned to a user has cost implications, and the higher quality of service may therefore require additional payments to the satellite network operator to ensure re-investment to enable a future increase in the size of the capacity pool.

4. CONCLUSIONS

The emerging generation of satellite broadband technologies has the potential to become an important medium for delivery of broadband to locations where it would otherwise not be cost-effective to offer high speed broadband. Bringing together simulation and user analysis, our interdisciplinary approach seeks to understand the casual requirements of rural users, to explore their expectations, determine the technology alternatives and to analyze acceptance/impact of offered solutions.

The paper identifies the key components that impact the conflicting challenges of cost and acceptable performance/user expectation. A key result is a better understanding of the flexibility of the system to address a breadth of requirements and support evolution of patterns of usage.

5. ACKNOWLEDGEMENT

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