ON-BOARD BROADBAND IN TRAINS: PROOF-OF-CONCEPT PHASE AND NEW BUSINESS MODELS

PART 1 – PROOF-OF-CONCEPT
Summary

This report presents the background for the proof-of-concept testing for on-train broadband and for new business models emerging from that. The participants of this study included, in addition to the Ministry of Transport and Communication and the Institute of Information Technology at the University of Jyväskylä, a group of IT companies and, naturally, VR (National Railway of Finland). There are two different versions of the final report: public and internal. Due to certain statutes governing publications of the Ministry of Transport and Communication, and in order to protect companies' intellectual capital, the contents of the public version have been modified to some extent. For this reason, the public version concentrates on general presentation of the proof-of-concept and contains a generic overview of the resulting new business models. The internal version is more detailed in its treatment of the proof-of-concept testing results, and some of its contents have been excluded from the public report.

1. INTRODUCTION

Between 15.04.2005 – 31.08.2005 the University of Jyväskylä conducted a feasibility study on installation of broadband in trains. The study investigated, from the technical and economical viewpoints, the feasibility of introducing on-train broadband and how both the train operator as well as the passengers could utilize it. When considering this utilization aspect the investigation also tried to clarify whether it would be possible to improve the range and quality of GSM reception with the help of broadband connection. In connection with the feasibility study a questionnaire was distributed to train passengers asking their opinions about Internet connection and the related services. More details of this can be found in "On-train Broadband Feasibility Study" published by the Ministry of Transport and Communication (www.mintc.fi).

The feasibility study showed that it would make sense to use several different wireless data transmission technologies for on-train broadband implementation. This would enable the use of each technology in its optimal environment resulting in maximally cost-efficient solutions. The solution outlined would, in practice, be very challenging to implement, but IBM who participated in the feasibility study indicated having found a solution for the implementation. That solution, however, has not yet been tested for example with the Flash-OFDM and WiMAX technologies – therefore, at this stage it is still not possible to guarantee that the proposed solution would be fully reliable. The Flash-OFDM, and WiMAX technologies proposed as suitable candidates for on-train broadbanding are so new that the information related to their functioning in mobile environments is still insufficient. Apart from being affected negatively by high train speeds, the propagation of radio signals can be affected by other factors such as electromagnetic fields in the environment. It is very difficult to predict or model the propagation of radio signals in such environments.

Due to the still existing technological uncertainties as discussed above, the feasibility study group decided to set up a proof-of-concept test in order to subject the solutions proposed in the feasibility study to practical tests. In addition to studying a connection router that would enable the use of several different technologies, the investigation also targeted the functioning of the WiMAX and Flash-OFDM technologies in moving trains.

2. Test environment

Two Pendolino trains in passenger use were selected as the test environment for the proof-of-concept testing. The idea initially was to install the broadband equipment into the business compartments of the two trains to allow measurements whenever the trains would travel between Helsinki and Tampere.

A Flash-OFDM test network with three base stations between Helsinki and Hyvinkää was designed. To test WiMAX technology, only one base station was employed, because the WiMAX version used was meant mainly for fixed locations and does not support switching between base stations. A manual implementation to achieve the desired configuration would have required excessive amount of work in relation to the scale of the test: it should be kept in mind that a version of WiMax for mobile environments that supports switching between base stations will get an approval at the turn of the year.

The idea was to test the connection router by connecting it to Flash-OFDM and WiMAX terminals using an Ethernet cable which would always select whatever technology at that particular point of time would give the best performance for data transmission.

When the test plan was presented to the Technical Installations Department of the VR Engineering, it was pointed out that the use of passenger trains as testing equipment for a test of such a short duration might not be a good idea, as not only would the testing require accurate and careful installations, but might also inconvenience passengers. Thus VR made it known that as the project was to be of short duration only, a special test Pendolino could be made available for it. For the proof-of-concept testing, this was a positive development: a desired number of test runs could be set up in succession, and the equipment could be configured and re-adjusted between each test run. It made it also considerably easier to install cables and other equipment, as the testing equipment could be openly displayed and was within an easy reach of the testing group. If the regular passenger trains in public use had been used in testing, the testing equipment would have had to be carefully hidden from the passengers.

The changes related to the selection of the test train caused also some changes in antenna installations. The different types of train carriages have varying structures, and these variations were also reflected in the locations available for antenna installations. Soon the

VR's installation department noticed that it would make more sense to install the antennas and other testing equipment into the restaurant carriage rather than into business compartments. Power supply and antenna cabling, in particular, were much simpler to implement in the restaurant carriage.

When selecting antennas and related equipment for Flash-OFDM tests, the trains' old NMT antennas turned out to be useful, because they utilize the same frequency range as that used in the Flash-OFDM technology. The restaurant carriage also had this type of antenna, thus that 450 MHz antenna just needed to be connected by a cable to a Flash-OFMD terminal. For the WiMAX technology there was no suitable antenna in the train, and, in addition to a cable, a brand new antenna was needed. A multifrequency antenna specially designed for use in trains that uses the same 3.5 GHz frequency as WiMAX was selected for the purpose. See Figure 1 below.

Figure 1. ***The antennas used in the test: an NMT antenna on the left, and a multifrequency antenna on the right.***

The length of antenna cable for the both types of equipment was 4 meters. It was desirable to minimize the length of cabling, because the longer the antenna cable used is the weaker its signal. RG214 cable that is quick and easy to install was used.

After the installation of the antennas and cables, the test group's Flash-OFDM and WiMAX sides were invited to test the functioning of the installations in the test train located in the Ilmala railway yard. The installations were found to be functioning correctly, and both of the terminals found the base station's signal. However, the signal of WiMAX was weaker than expected, and it was decided to confirm the test result by measuring the strength of the signal with an antenna that had a gain similar to that of the multifrequency antenna and that was hold by hand at the train door. The signal measured at the door of the train proved to be 11 decibels stronger, which suggested that the antenna installed on the roof might have experienced some problems. On checking the cables the connection line seemed to be in good condition, and it was surmised that the cause for the weak signal might have been somewhere in the installation environment. However, one could not be certain about that, and it was decided to conduct the first WiMAX test with the existing equipment configuration.

In addition to tests conducted with trains, tests were also conducted with a separate measurement car which had a small mast on the roof for antennas, and a power supply for terminal equipment in the interior. The tests conducted using the car proved to be even more flexible than the tests with the test train: test locations that were found to be problematic, such as the switching areas between base stations, could be efficiently tested several times in a very short space of time.

3. Test process

In total, there were two testing days during which the testing took place in the train. Between these two days there was a one and half week time lapse allocated for solving possible problems. In addition to the tests in a moving train, the functioning of the different technologies was investigated with the measuring car and in a train that was stationary.

The tests were conducted during evenings and weekends. At those times there was very little other traffic in the Helsinki-Hyvinkää railway section, and for the tests these times clear of traffic were ideal. The testing progressed at a good pace, and at no times were there any waiting periods that would have interfered with the testing. The effect of the speed could be effectively studied in the uncongested track. There was a chance to adjust the settings of the equipment at both ends of the track when reversing the train direction, after which the effect of the changed settings on the functioning of the equipment could be investigated forthwith.

4. Summary and discussion of the proof-of-concept testing

The Flash-OFDM technology positively surprised the test group, because it functioned reliably in a moving as well as in a fixed location. Even speeds of 200 km/h had very little effect on the functioning of the technology. This indicates that Flash-OFDM would suit exceedingly well for on-train broadbanding. However, when looking at the results of these tests, one should keep in mind that during the measurements there was hardly any other load on the base stations.

The WiMAX part of the testing also provided some positive results, although the current WiMAX technology for fixed locations is not ideal for mobile uses. There were no problems with the reception of the signal itself, but the reliability of its data transfer connection needs some further development. Currently this issue is being addressed by many multinational companies. Mobile WiMAX standard will strengthen the position of WiMAX technology in on-train broadbanding. This testing alone showed that the multiway propagation used in WiMAX enables signal reception without a line-of-sight between a base station and a terminal device. It is probable that the equipment designed for mobile use will benefit the

WiMAX technology also by adding to it the properties that are required of the equipment for on-train broadbanding.

The working principle of the connection router, which was used as the third testing component, is interesting. One can ignore the endless disputes about the various technologies and their comparative superiority over others, because with the help of the connection router it is always possible to determine the most suitable data transfer technology for any particular situation to maximize the cost-efficiency ratio. It is probable, that in the future similar solutions will be integrated in increasing numbers to different systems ranging from terminal devices to connection routers. It is apparent, when looking at the results of the testing, that when installing and configuring a connection router one should be prepared to face the challenges posed by new radio systems and their terminal equipment. Most often there is a solution to be found for great many of the possible problems that may occur, and in this time also a functioning end result was obtained.

On the whole, the proof-of-concept testing in the on-board broadbanding project provided a great amount of useful measuring data and information about different technologies and their functionality in a moving train. The testing mainly aimed at presenting technological capabilities. A larger scale pilot research is required for collecting wider user experiences to investigate for example the effect of the user loading on the functioning of the solutions investigated. Some of the solutions that were found technically feasible here could be tested.

PART 2 – BUSINESS MODELS
1. Contents of the study

The aim of the study modeling earning logistics and business activities was to create a base from which to estimate, keeping the commercial viewpoint in mind, those economic factors that need to be taken into account in the construction of broadband technologies, in their maintenance and in content offering.

The study produced a normal business planning simulation model (income and financial planning) and 2-3 alternative earning logistics scenarios where the following economic starting points were used as the parameters:

- investment costs for technical systems
- technical support and other maintenance related to on-board broadband
- broadband usage and user numbers
- user fees
- sponsored contents and media sales

The report of the study is in the form of a PowerPoint presentation[1] which can be used as a tool for further planning and for presenting the idea's potential for other activities.

2. A tool for earning logistics and business planning

The tool that can be used for estimating business activity and its earning logistics is in the form of Excel worksheets, in which the reports created with the help of the calculation parameters described above can be used as a base to estimate the economic dimensions of the activity. The reports on the worksheets are:

1. Summary of the business indicators
2. Income plan for the first three years.
3. Financing plan (3 years)
4. Report in the form of an income statement and a balance sheet (1st year)

There are two stages in the use of the worksheets:

1. Information about investments and operating costs is entered into "Investments and Operating costs" sheet in the workbook.
2. Other calculation parameters can be changed in the "Business activity details" sheet where the effect of these parameters can be observed in relation to income and financing.

1 The word "positioning" used in the presentation refers here to a competetive advantage that can be achieved when entering the marketplace.

Figure 2. BROADBAND TRAIN business environment

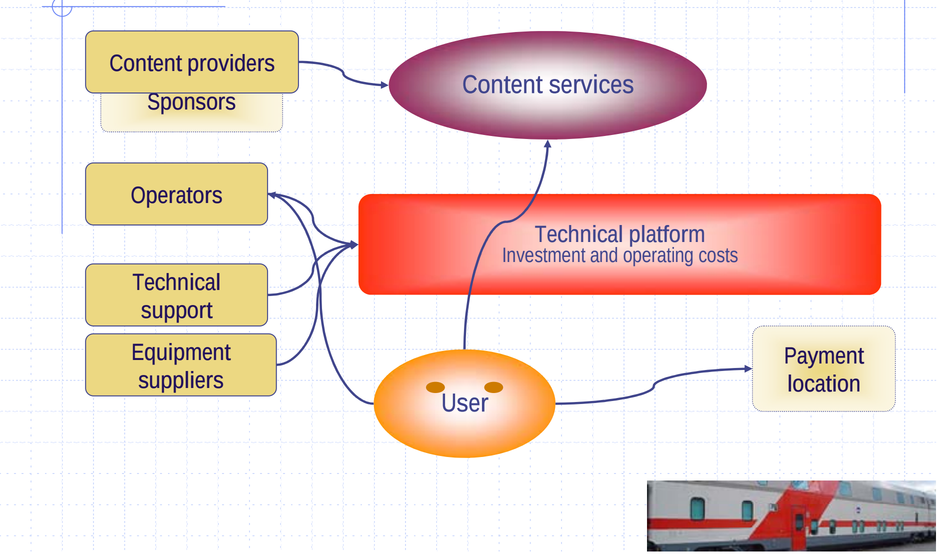

Figure 3. Contents for the project's economic model

- The aim is to
  - estimate, keeping the commercial viewpoint in mind, those economic factors that need to be taken into account in the construction of broadband technologies, their maintenance and content offering
  - create a calculation tool for later use
- Utilization of the results
  - as a tool in the creation of the final business model
  - The project will define the most pertinent concepts related to the business model and its earnings logistics. In the pilot phase, these can be pinpointed with the help of a user survey.

Figure 4. Project stages for the business plan

1. Development of the business environment
   - Technical development, investment and operating costs - also for the future
   - Content potential and costs
   - User expectations and user willingness to pay for the service
2. Aims
   - Definition of economic gain, and risk management
   - Direct and indirect earning modes
3. Methods for reaching the aims
   - Marketing and other communication
   - Concrete emphasis on sales
4. Resources
   - Technical structure and personal services
   - Time spans for the planning and consideration of activities

Figure 5. The basic starting point for the project's economic model:

- Is on-board broadband
  - an interesting and necessary service for the passengers -> with willingness to pay?
  - profitable business?
  - an additional free service for the passengers?
  - an opening for a novel business activity?
  - a useful component of a multimedia network?
  - a service for which there won't be any easy and/or economic alternative in a foreseeable future?

Figure 6. Starting points for the project calculations:

- Participants in the investment
  - Service providers and other participating entities
  - Public investment support?
  - A separate company as a starting point in the calculations, direct responsibility for costs
- Participants in the operating costs
  - Content providers (media, e-trading companies)
  - Usage fees (credit card etc. payments)
- Payment methods for the user
  - A separate payment for the service used or no payment at all
  - One-time payment / monthly fee (operator activities)
- Earning logistics for the supporting services?

Figure 7. Project viewpoint and effort invested

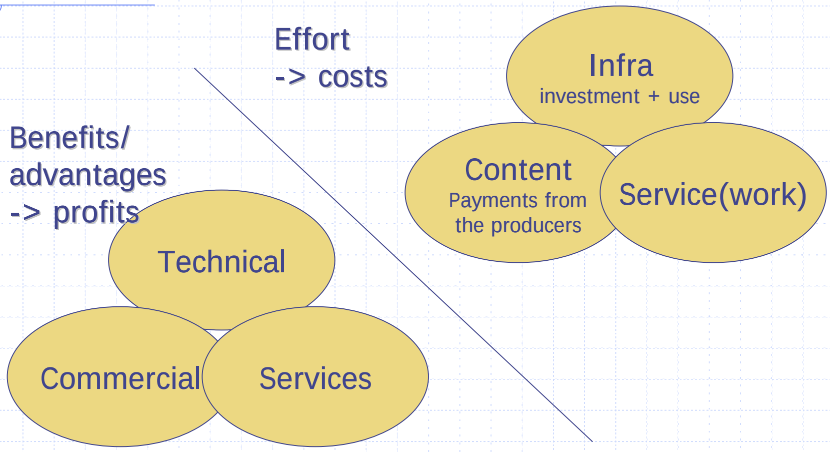

Figure 8. Project's business model

- Starting point: a one-time investment on equipment for 18 Pendolino train units
  - Information technology investment: € 579 000 in total
  - The invetment and operating costs in these calculations are based on offers received by Tapio Väärämäen (JY)
- Support and maintenance as decisive factors in operating costs
  - Just one offer received: €1500 /mth/train unit -> € 354 000 per year
  - A more realistic offer would probably be 30-50% of the offer above supposing all the 18 train units were being used simultaneously
- Required level of turnover: € 500 000 (bidding related)
  - In the calculation model, finance with 5% interest (paid in 5 years), of the investments 25% expense depreciation
- Turnover from:
  - VR's internal use (€/mth/train unit)
  - passengers (€/access/train trip)
  - Content producers (€/mth/train unit)

Figure 9. Project calculations

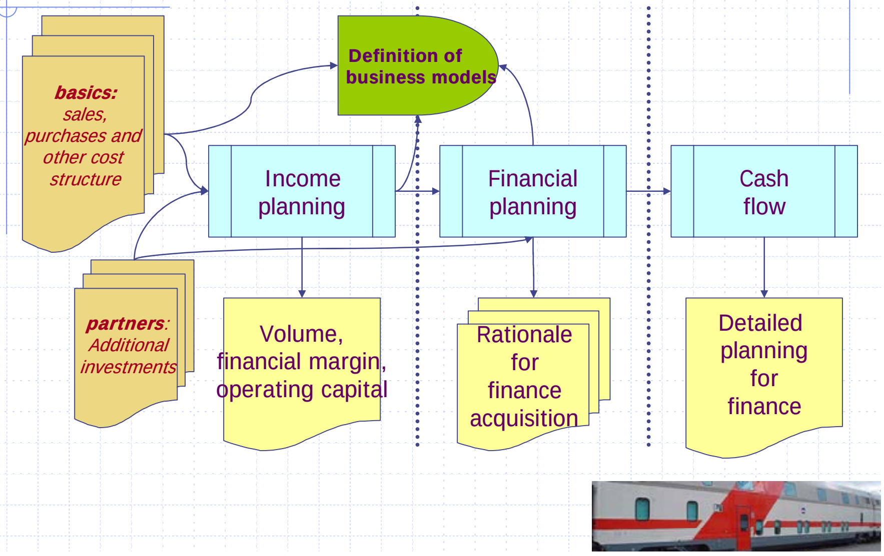

Figure 10. BROADBAND TRAIN: Technical position