Service Availability Classification for Trunked Radio Network Used in Municipal Transport

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Municipal transport usually requires a dedicated radio network where the transmission is strongly affected by high density population areas with many tall buildings. Therefore the frame loss ratio parameter is the most crucial parameter affecting communication with municipal transport vehicles. The paper deals with a mathematical proposal of service availability classification for municipal transport vehicles based on frame loss ratio related to stops included in a vehicle route. For the purpose of obtaining values needed for the proposal, a long-term measurement has been processed. Finally, an example is given how to calculate the communication availability for municipal transport vehicle.

Keywords: trunked radio, service availability, frame loss, municipal transport

1 Introduction

Municipal transport (MT) has a dominant influence on the quality of life in large cities. The towns, which today extend on areas of hundreds of square kilometres, consider MT today a very important functional element. It also affects people's psyche, makes them waste their time and brings additional expenses and other limitations. In ideal MT there is typically a regular sequence of vehicles, which however are loaded variably, depending on actual demand. By contrast, MT has rather a constant number of passengers in the vehicles, but the stream of MT vehicles fluctuates according to users' demands. The process of regular MT is ever more frequently exposed to external interference, which can lead to MT being sometimes unpredictably irregular and difficult to control. If a complex MT system is left in this unsteady condition, then a failure of one vehicle will spread and, within a brief time, affect a number of distant locations and tens of thousands of MT passengers. Newly introduced elements from the viewpoint of MT communication are data transmission systems using trunked radio networks. This data transmission aim is to offer better possibilities of operating MT vehicles.

2 Trunked Radio Network

The recently increased demand for mobile communication calls for more efficient methods of using the current frequency spectrum. A trunked network [1] uses several channels for a lot of subscribers (MT vehicles). If a call is requested, one of the free channels is assigned to vehicles demanding a call. The control channel is used for the assignment of channels. In this way, there can be, for example, 1000 vehicles served by 10 channels in a very short waiting time. The channel assignment is controlled by a computer. A trunked network like a mobile network is divided into cells. The cell size depends on the density of population in an area to be covered (there are smaller cells in towns and bigger cells in an area with smaller density of population). Each cell consists of several radio stations. The cells are connected to the Operating Maintenance Centre. Both direct and broadcast calls can be done in a trunked network. A trunked network can be connected to a public switched telephone network (e.g. via private branch exchange). An example of trunked radio network can be the MPT 1327 [2] or Terrestrial Trunked Radio - TETRA [3].

3 Measurement of Trunked Radio Network

3.1 Measurement purpose and conditions

This section describes a long-term measurement of MPT1327-based trunked radio network used by MT in the city of Ostrava, Czech Republic. The Ostrava city municipal transport company has about 537 vehicles (210 trams, 51 trolleybuses and 276 buses) operated at peak traffic time. The operating control transmitter has a power of approximately 5W. The covered area is about 12km. The main measurement purpose was to monitor the communication between the operating control and MT vehicles. The measurement was based on the evaluation of dedicated message transmission between the transmitter and vehicles in the request-response mode. The transmission was processed within an indefinite loop with all vehicles currently in operation.

3.2 Evaluation of measured values

This section discusses some of the results measured. All the values presented are related to the most important parameter, the frame loss ratio. The values measured (312 thousand MS Excel rows) were processed using software developed for that purpose. Since the transmitter communicated with three kinds of MT vehicles, we were able to distinguish the results for the following types of vehicles, see Tab. 1.

Tab. 1: Frame loss for three types of MT vehicles

	Tram	Trolleybus	Bus
Frame loss [%]	29.2	35.9	24,5

We suppose that the big variety in frame loss is due to the different types of engines used. Buses have diesel engines, but trams and trolleybuses use electromotors with powerful transducers. This equipment is possibly the source of radio interference. The second possible reason is the vehicle route. Usually, trams and trolleybuses are operated in highly populated areas with many tall buildings.

The frame loss dependence on time is depicted in Fig. 1. The average value is about 23.6% for all types of vehicles used. The graph also shows that there is a small increase of frame loss between 8 and 12 a.m. We think this is due to the greater industry

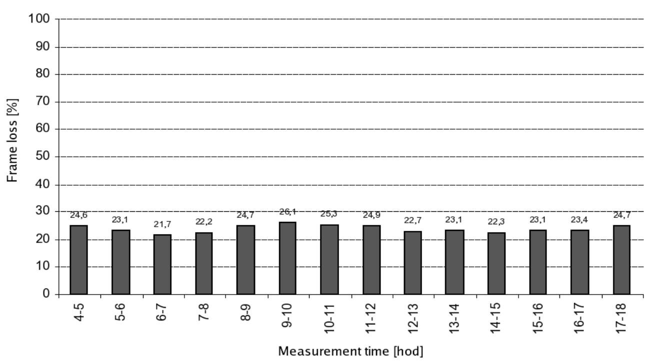

Fig. 1: Frame loss dependence on time hours

interference in those hours.

The last evaluated and the most important value was the frame loss dependence on the distance of MT from operating control transmitter. Unfortunately, MT vehicles were able to report only one item of position-related information - their actual MT stops. Therefore, the distance between 72 MT stops and the transmitter were evaluated using a map of Ostrava. The resulting map with some MT stops with frame loss is shown in Fig. 2. The calculated frame loss dependence on distance between MT stops and the transmitter is shown in . The graph shows that the frame loss does not decrease with distance as could be expected. The black line represents the trend connecting line. The smallest values are approximately at the distance of 1600 m from the transmitter. At closer distances (500 m), the frames loss is slightly increasing. We think the reason for that variety is the interference of direct waves and waves reflected from the surrounding buildings. Moreover, the transmitter antenna itself could not cover all near area due to vertical radiation aperture.

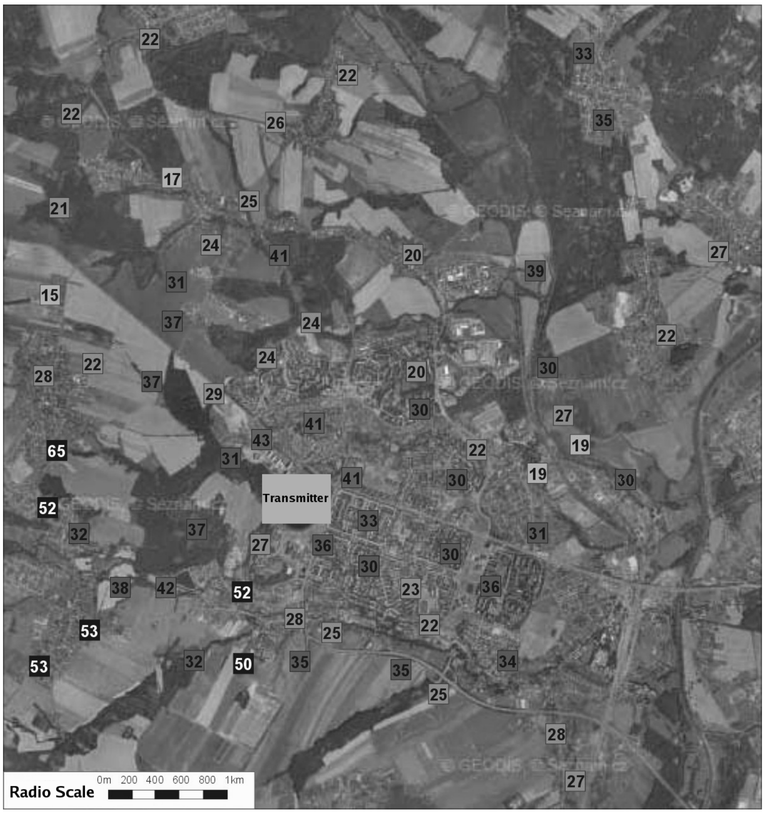

Fig. 2: A map of some MT stops with frame loss

4 Service Availability Classification for MT Vehicles

4.1 Service availability theory

Service availability is a part of general QoS (Quality of Service) evaluation. A selected set of parameters is used for QoS description. Mutually independent parameters are called primary parameters. Primary parameters are organized into a 3×3 matrix [4]. The main features of the matrix are as follows: each row represents one of the three basic and distinct communication functions (speed, accuracy, dependability); each column represents one of the three possible exclusive outcomes when a communication function is attempted (access, user information transfer, disengagement). In the case of trunked radio network, we are interested in the data link layer of the OSI reference model. Therefore the first column (connection establishment) and the last column (disengagement) are omitted. The reduced matrix is shown in Tab. 2.

Tab. 2: Primary parameters of data link layer

Function		
Speed	Accuracy	Dependability
Transfer rate Transfer delay Transfer delay variation	Frame error ratio **Frame loss ratio**	Spurious frame ratio

Secondary parameters are derived from the primary parameters. The secondary parameters are used to express the service availability function. In our case, we call it the MT vehicle service availability. A specified availability function compares the values of a subset of primary parameters with the corresponding outage thresholds to classify the service as available or unavailable during a scheduled time. The availability then characterizes the resulting binary process, which results in the values: 0 – service unavailable, 1 – service available [5].

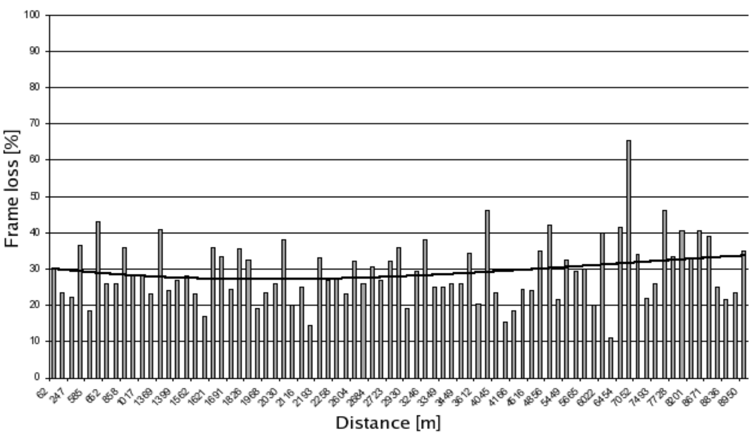

Fig. 3: Frame loss dependence on distance between the transmitter and vehicles

4.2 Proposal of service availability classification

Modern communication systems are usually designed to satisfy the rule of „five nines number", which means that a system should be available for 99.999% of operation time. As the MT communication system is considered, we assume an important starting point: the MT operating system should be able to communicate with a MT vehicle at least once between two MT stops. In other words, the service or communication is available when the probability of successful transmission *P(ST)* between two MT stops has the value of 99,999%, and, consequently, the probability of transmission failure *P(TF)* has the value of 0.001%.

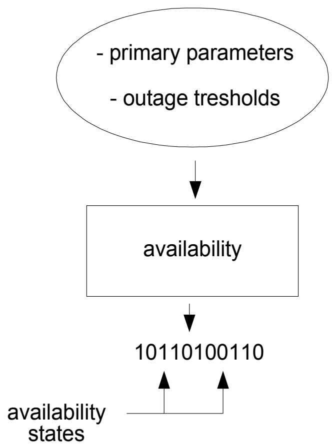

Fig. 4: Service availability function

Usually there are several transmissions with a MT vehicle while moving from one MT stop to the following. The number of transmissions *tr* between two stops is calculated as

$$tr = \frac{t_{stop}}{t_{req}} \quad (1)$$

where t_{stop} is the average time of vehicle moving from one MT stop to the following, and t_{req} is the transmission interval for a MT vehicle in a loop. Let us assume that a frame sent from the transmitter to the vehicle can be repeated *fr* times if the transmission fails. The probability of transmission fault *P(TF)* could be then identified as

$$P(TF)=P(FL)^{fr} \tag{2}$$

where *P(FL)* is the probability of frame loss. Considering the number of transmissions between two stops *tr*, the probability of system fault *P(SF)* is identified as

$$P(SF)=P(TF)^{tr}=P(FL)^{fr\times tr} \tag{3}$$

From the equation above, we can then calculate the maximum allowed frame loss ratio *P(FL)* for a given probability of system fault *P(SF)*

$$P(FL)=\sqrt[fr\times tr]{P(SF)} \tag{4}$$

Now, we are able to calculate availability function S_n for a MT stop *n* as

$$S_n=\begin{cases}1\,; P(FL_n)\leq P(FL)\\ 0\,; P(FL_n)>P(FL)\end{cases} \tag{5}$$

where $P(FL_n)$ is the probability of frame loss for stop *n*. The problem is that we usually need to know the availability function not only for one stop but for the whole vehicle route. Therefore, the availability function for all MT stops included in a route has to be evaluated. Then, the service availability for a route S_t is identified as

$$S_t=\begin{cases}1\,; \sum_{n=1}^{N} S_n=N\\ 0\,; \sum_{n=1}^{N} S_n<N\end{cases} \tag{6}$$

where *N* is the total number of stops for a route.

4.3 Availability function for MT vehicle route

To calculate the proposed service availability, we need to know the average time of vehicle to move from one MT stop to the following. From measurement results, this takes approximately 2 minutes (including delay at traffic lights and so on). Also we need to know the loop transmission interval of a vehicle. From the measurement, it was identified to be every 25 seconds. Therefore using equation (1), the number of transmissions between two MT stops *tr* is approximately 5.

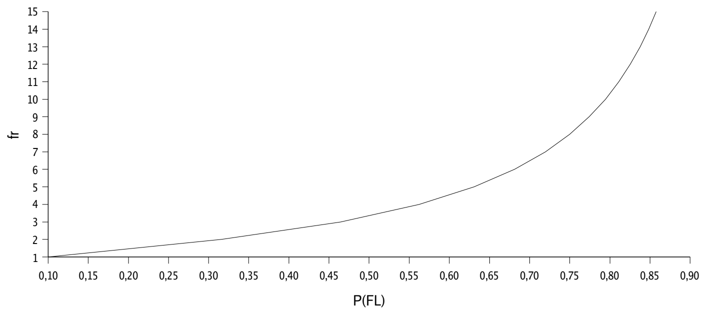

Fig. 5: Maximum frame repetition needed to achieve the 99.9999% communication availability

Furthermore, we know that the MT communication system uses maximum frame request repetition *fr* equal to 5. Therefore from equation (4), the maximum probability of frame loss *P(FL)* is identified as

$$P(FL) = \sqrt[5\times5]{0{,}00001} = 0.63$$

The value *P(SF)* is 0,00001 as we chose before. Finally, we can easily calculate service availability for MT stops included in the route S_n and the final service availability for the whole route S_t.

5 Conclusion

The significance of QoS is still growing and its evaluation is crucial, for example, when setting up new services. The proposed service availability evaluation for trunked radio network used in MT can be used, for example, when designing a new MT vehicle route. The concrete steps to set up a new route could be to create a set of MT stops envisaged, then assign the measured frame loss ratios for these stops, and finally, using equations (4), (5), (6), calculate the service availability for the new route. If the function fails, there are some possible simple enhancements. A MT stop with the biggest frame loss ratio could be replaced with another one with a lower frame loss ratio or the maximum frame repetition *fr* could be increased to meet the service availability function requirement as shown in Fig. 5.

The proposed availability classification should help MT companies offer better control of MT vehicles. Since MT is sometimes unpredictably irregular, improperly managed control can lead to unsteady operation of MT. For example, the failure of one vehicle could spread within a brief time and affect a number of distant locations and tens of thousands of MT users. Therefore a MT vehicle should communicate with the MT operating centre in small periodic intervals to report its actual operating state.

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6 References

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