Channel classification with hidden Markov models in mobile networks

Rafiaa Boujbel

Department of Electrical Engineering and Information Technology
Munich University of Applied Sciences
Lothstr. 64
80335 Munich
rafiaboujbel@hotmail.fr

Abstract: In telecommunication networks, Key Performance Indicator (KPI) is monitored to ensure the connection quality. Many indicators are provided by the network equipment in order to ensure higher Quality of Service (QoS) in communication networks. With the significant increase of data traffic on the mobile network, a detailed analysis of the transmission quality is becoming increasingly important. Existing classification approaches are widely considered for network traffic classification and not the channel in itself.

The aim of this work is to develop a channel estimation tool based on hidden Markov models that is able to determine transmission channel characteristics in mobile radio receivers.

1 Introduction

In the field of telecommunications engineering, the term channel refers to the medium between a transmitter and a receiver. The characteristics of wireless signal changes as it travels from the transmitter to the receiver. These characteristics depend upon the distance between the two parts, the signal path, and the environment around the path. A channel model, a model of the medium between the two parts, is used to obtain the profile of the received signal from the transmitted signal. Due to the enrichment of services and data traffic on mobile networks (e.g., downloads, videos in high resolution), channel classification is becoming crucial to ensure a favorable network quality for the user.

On the one hand, channel classification is widely associated to GSM and wireless. On the other hand, existing classification approaches are based on the network traffic and not the channel in itself.

The aim of this work is to combine channel classification and new generation mobile networks. This classification is based on hidden Markov models (HMMs) [GDM11] which are widely used and accepted in the field of digital communication. From the receiver side, a channel classification is useful for giving an overview of the channel conditions. The general idea is to provide users an estimation tool of the channel with an easy access. The role of this tool is to give the operator an estimation of the quality and the characteristics of the transmission channel in order to assure a good use of the channel in mobile networks.

2 Approach

Consider the case of Single-Input Single-Output (SISO), packets are created and sent in a central network unit (e.g. Operation and Maintenance Center (OMC)). In the mobile radio channel, the signals are disrupted and delayed, depending on the characteristics of the channel. Due to transmission error, data packets are retransmitted and lead to delays in the corresponding IP packets. These delays depend on the packet length, the type of packet error and the used mechanism of correction namely Automatic Repeat Request (ARQ) or Hybrid Automatic Repeat Request (HARQ) [Ge11]. The evaluation of the measured jitter of the IP packets, the packet loss, and possibly higher protocol layers such as RTP leads to estimate the occurred packet error in lower layer. As it is shown in figure 1, sequence errors are generated from jitter. Received packets are converted to “1” in the case of error and “0” in the case of error-free.

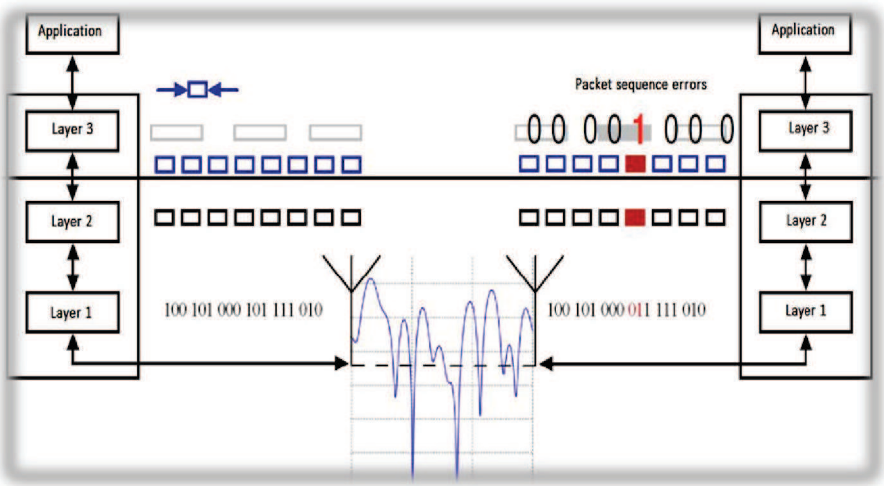

Figure 1: Schematic diagram of generating sequence errors

The functional blocks shown in figure 2 are the subject of this work, namely the channel models database and the channel estimator.

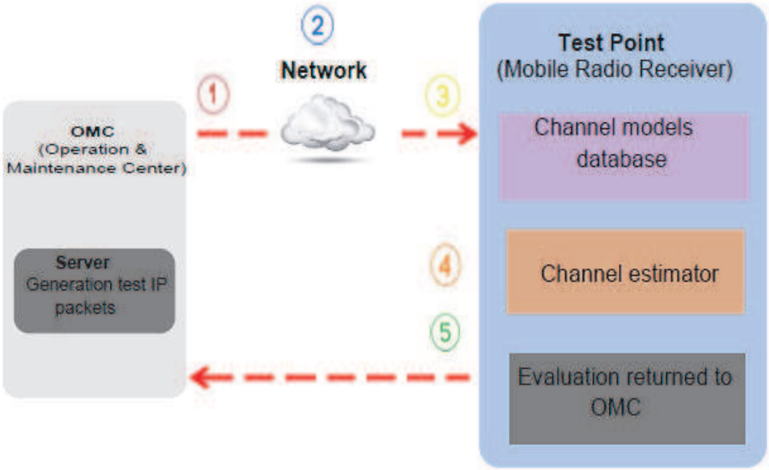

Figure 2: Functional model for channel classification in mobile networks

2.1 Channel models database

Channel models database is a database of models and precisely of HMMs. These models have been provided from a radio channel simulator on the basis of known channels. To simulate the external environment, a wireless channel emulator is used to emulate wideband radio channel characteristics such as fading profiles which are defined in the 3GPP standard.

These HMMs are built specially from sequence errors. Sequence errors are generated from Acknowledgement (ACK) and Negative- Acknowledgement (NACK) protocol message. ACK and NACK are collected via a reliable tool and sequence errors are generated as fellow: in case of erroneous packet, a NACK is received and converted to error “1”. In case of error-free packet, an ACK is received and converted to “0”.

2.2 Channel estimator

The inputs of the channel estimator are two models. The first model is a HMM already stored in the channel models database. The second model is a HMM generated from the measured signal. In this case, sequence errors are generated from inter-packet delay. When the inter-packet delay is higher than a certain threshold then an error is considered and a “1” is generated. When the inter-packet delay is lower than a certain threshold then an error-free is considered and a “0” is generated.

This channel estimator consists of the metric Kullback-Leibler Distance (KLD) [SY11] [ZL12]. The KLD is used to compare the similarity between these two models described above. Smaller is the KLD; bigger is the similarity between the models.

The outputs of the KLD algorithm are the channel model used and the condition of the channel. These informations are sent back as a result to the OMC.

3 Results

Considering the case of Long Term Evolution (LTE) network, a couple of measurements are done in order to guess the channel conditions used within the network. These channel conditions are namely different fading models. As it is defined in the 3GPP standard, LTE fading models are divided in low fading namely Extended Pedestrian A model (EPA5), medium fading namely Extended Vehicular A model (EVA5/EVA70) and high fading namely Extended Typical Urban model (ETU70/ETU300). The idea is to take two measurements with two different channel conditions: One measurement with good channel conditions (EPA5) and the other one with bad channel conditions (ETU70).

Assuming that we do not know the channel fading conditions used and we try to estimate them via the channel estimator.
From the received signals of our measurements, sequence errors are generated as it is described above. The channel estimator, precisely the KLD algorithm, is used to measure the distance between the sequence errors generated and each HMM stored in the channel models database. As it is shown in the tables below, the smallest absolute distance is considered and the model is classified in the channel that corresponds to the smallest distance.

Actual	**Predicted**				
	EPA5	**EVA5**	**EVA70**	**ETU70**	**ETU300**
EPA5	**231.66**	250.36	321.23	394.16	395.17

Table 1: KLD between EPA5 sequence error and HMMs in database

Actual	**Predicted**				
	EPA5	**EVA5**	**EVA70**	**ETU70**	**ETU300**
ETU70	791.35	515.92	457.29	**156.91**	226.70

Table 2: KLD between ETU70 sequence error and HMMs in database

4 Conclusions and outlook

Network traffic classification is the basis of numerous network applications. The classification method used in this work is based on HMM. Experimental results indicate that the combination of channel characteristics and statistical models leads to precise model and achieve higher classification accuracy.
As a continuation of this work, an investigation of Multiple Input Multiple Output (MIMO) channel classification is becoming crucial. The MIMO technology is promising to be one of the key techniques for wireless communications beyond 3G, for its high spectrum efficiency and reliability.

Therefore, extracting jitter values from the received signal without expensive measurement devices and adapting results found to the MIMO technology are the key point for future work.

Acknowledgments

This project is promoted by the Bavarian Ministry of Economics, Infrastructure, Transport and Technology and it is performed in cooperation with Keynote-SIGOS GmbH.

References

[GDM11] Güzelarslan B, Dippold M, Paul M.: Efficient and automatized error pattern modelling with hidden Markov models in digital communication. AEUE, 2011; pp. 417-424.

[Ge11] Gessner, C.: A concise introduction to LTE and its measurement requirements. Rohde & Schwarz, Germany, 2011; pp. 83.

[SY11] Sahraein. M, Yoon. B.: A Novel Low-Complexity HMM Similarity Measure. IEEE, 2011; pp. 87-90.

[ZL12] Zhen-Hua L, Li-Rong D.: Minimum Kullback-Leibler Divergence Parameter Generation for HMM-Based Speech Synthesis. IEEE, 2012; pp. 1495-1497.