Data Interleaving for Congestion Reduction in Mobile Traffic Transmission

Hemant Purohit
Department of Electronics & Communication Engineering (ECE),
Jodhpur Institute of Engineering & Technology (JIET),
Jodhpur, India

Dmitry Korzun, Anton Shabaev, Anatoly Voronin
Institute of Mathematics and Information Technology (IMIT),
Petrozavodsk State University (PetrSU)
Petrozavodsk, Russia

Contents

- Traffic Congestion Problem
- GSM Networks (as well as 5G/LTE)
- Reference Model for Data and Voice Traffic
- DITMC (Data Interleaving Technique in Mobile Communication) Based Methodology
- Initial Experimental Indication
- Applying DITMC in other domains
- Conclusion and Future work

Traffic Congestion Problem

- Limited allotted spectrum involving voice communication and data communication in mobile networks
- Poor communication services: incomplete calls, call drops, slower Internet speed, higher cost of internet service, and other undesirable effects by the service providers
- The bandwidth saturation and congestion conundrum still remain critical research area
(especially with emerging multitude of edge and intermediate Internet devices)
- Data Interleaving Technique in Mobile Communication (DITMC)

In GSM Networks (1/3)

- In 2016, global mobile data traffic amounted to 7 ExaBytes (EB) per month. In 2021, mobile data traffic worldwide is expected to reach 49 EB per month at a compound annual growth rate (CAGR) of 47%. According to the Ericsson report on mobile traffic growth, summarized in Table I. In particular, by the end of 2022, there will be 12 times more mobile data traffic in Central and Eastern Europe and Middle East and Africa (CEMA).
- In Russia, according to CISCO VNI (Visual Networking Index) Mobile Forecast Highlights, it is predicted the average smartphone will generate 6,350 MB of mobile data traffic per month in 2021, compared with 1,792 MB per month in 2016.
- The average mobile-connected laptop will generate 6,285 MB of mobile data traffic per month in 2021, compared with 2,821 MB per month in 2016. There will be 97 million total Internet users (68% of population) in 2021, compared with 86 million (60% of population) in 2016. The average mobile-connected tablet or smartphone will generate 7,055 MB of mobile data traffic per month in 2021, compared with 2,584 MB per month in 2016.

In GSM Networks (2/3)

- In India, consumer mobile traffic will grow 7.4-fold from 2016 to 2021, a compound annual growth rate (CAGR) of 49%. Consumer mobile traffic will reach 1.8 EB per month by 2021, compared with 238.0 Petabytes (PB) per month in 2016.
- Everyday mobile activities such as mobile social media usage, including mobile chat and voice or video calls, and mobile ecommerce drive mobile traffic but mobile video has the largest growth rate out of all of the mobile content categories. Between 2016 and 2022, smartphone traffic is expected to increase by 10 times and total mobile traffic for all devices by 8 times. By the end of this period, mobile data traffic will preemptively more than voice traffic.

In GSM Networks (2/3)

Expected Mobile Data Traffic (as per report by Ericsson)

Mobile Data Traffic by Region	2016 (EB per month)	Multiplier 2016-2022
Asia Pacific	**3.6**	**8**
CEMA (Central and Eastern Europe, Middle East and Africa)	**1.8**	**12**
Western Europe	**1.2**	**8**
North America	**1.2**	**6**
Latin America	**0.7**	**8**

Reference Model for Voice and Data Traffic (1/3)

- For the voice traffic, the calls are assumed to follow the Poisson point process with rate λ_v, i.e., the probability of n concurrent calls in the network is defined as

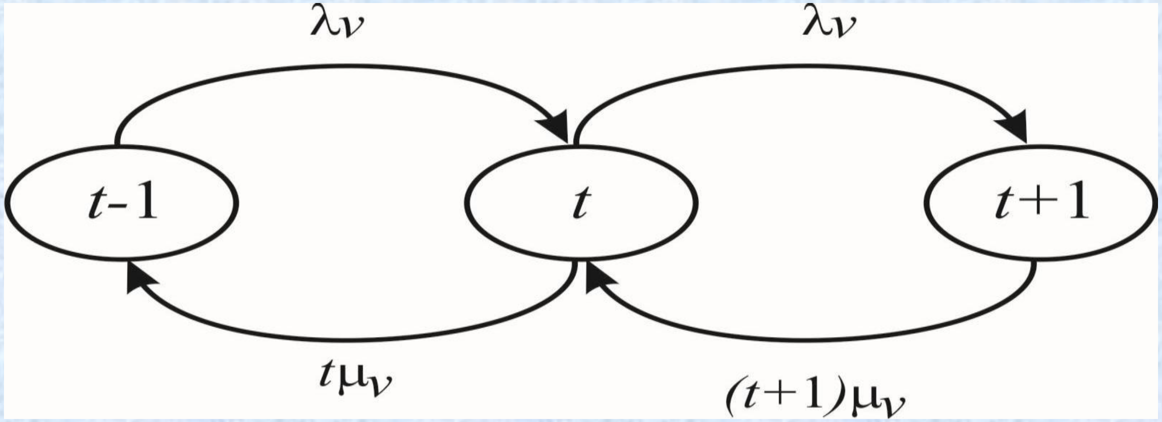
$$\mathbb{P}(N = n) = \frac{\lambda_v^n}{n!} \exp(-\lambda_v)$$

- The duration of each call is distributed exponentially with the parameter μ_v, i.e., the duration τ_v is less than x with the probability

$$\mathbb{P}(0 \leq \tau_v < x) = \mu_v \exp(-\mu_v x)$$

Reference Model for Voice and Data Traffic (2/3)

Reduced to the Markov chain for the voice traffic with discrete time-slots *t*



In the TDMA scheme (Time Division Multiple Access), the total number TS of timeslots is partitioned into the sets:

- TSv time-slots are dedicated to voice calls
- TSvd time-slots are shared between voice and data traffic
- TSd time-slots are dedicated to data transmission
- Then TSd + TSvd time-slots are on a single TDMA, which has total of 8 time-slots

Reference Model for Voice and Data Traffic (3/3)

Denote $\rho_v = \lambda_v / \mu_v$.

The model has the unique steady state

$$p_v(t) = \frac{\rho_v^t / t!}{\sum_{i=0}^{TS_v} \rho_v^i / i!}, \quad t = 0, 1, \dots, TS_v$$

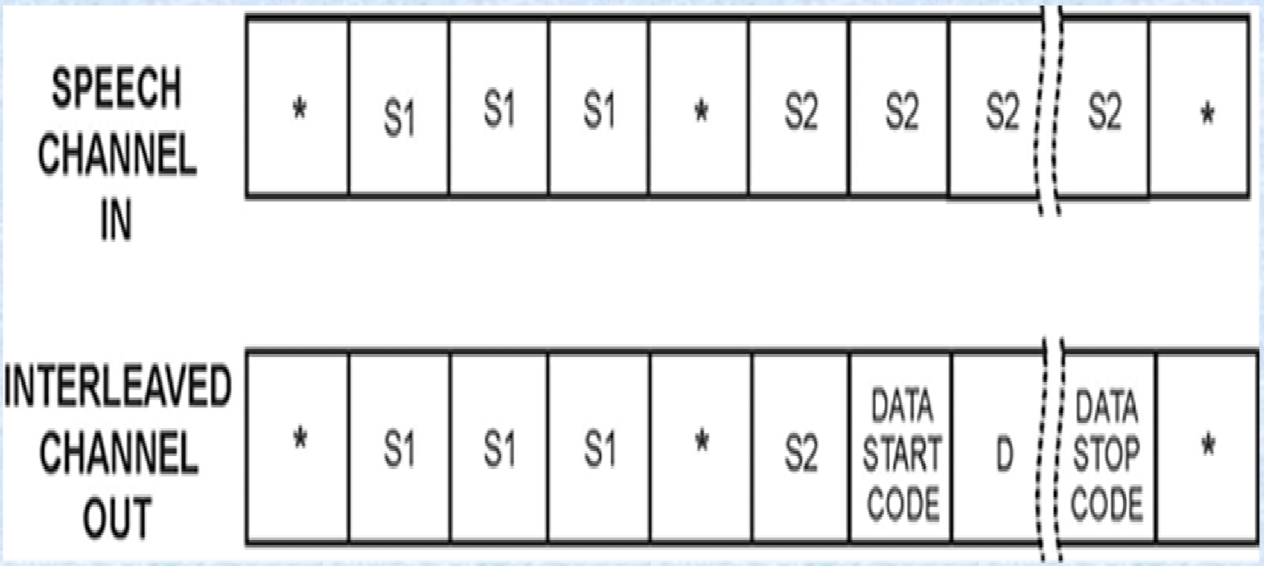
The performance metric can be represented by the blocking probability (also known as Erlang-B formula)

$$B_{v,cp} = \frac{\rho_v^{TS_v} / TS_v!}{\sum_{i=0}^{TS_v} \rho_v^i / i!}$$

DITMC: Data Interleaving Technique in Mobile Communication

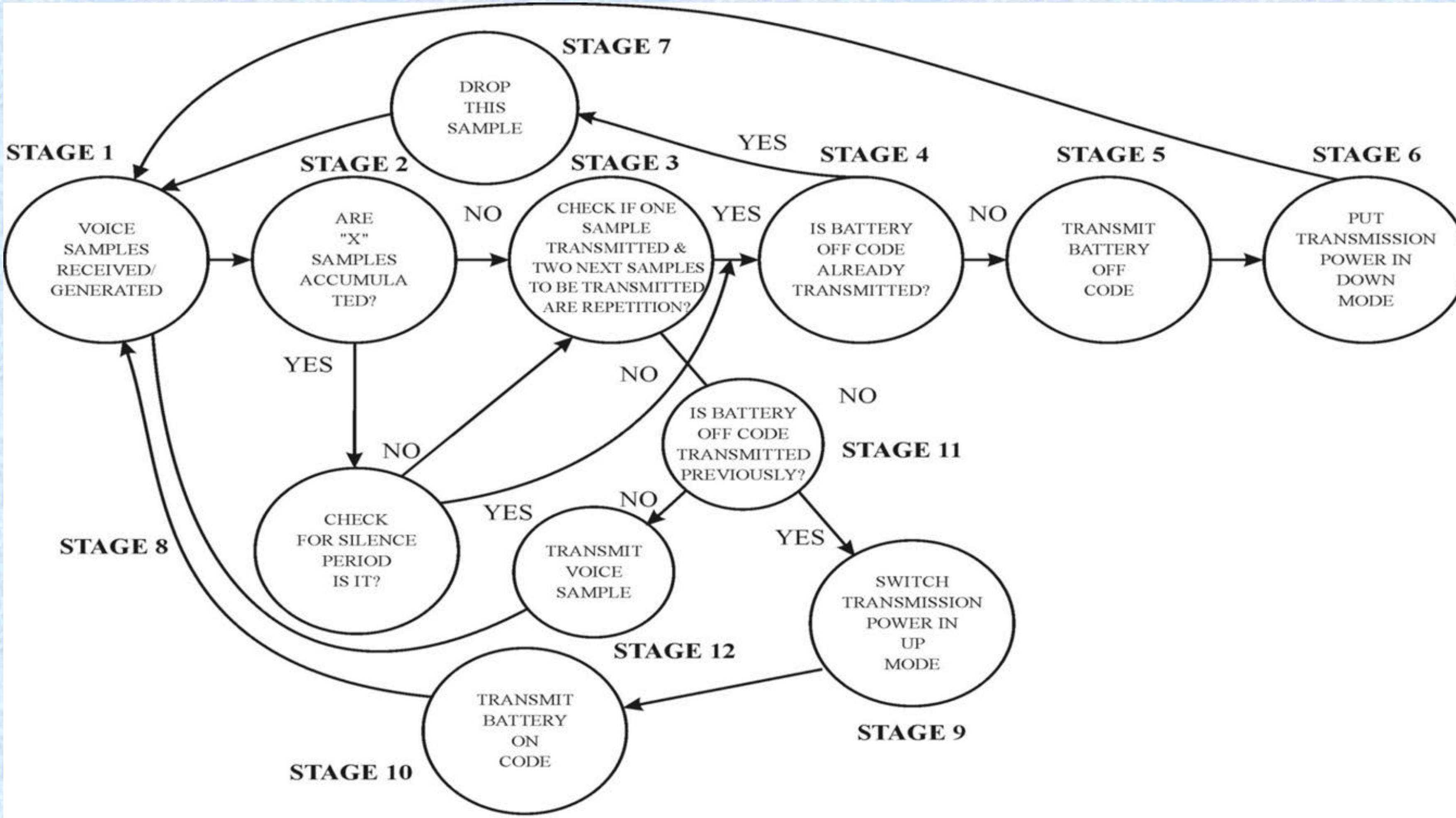
- DITMC involves the dynamic utilization of the channels by considering the repetition in voice bytes and the bytes generated due to silence period in any call
- Whenever the repetition of bytes is 4 (four) or more, a Battery OFF Code (Data Start Code) is transmitted (after the first voice byte). This was, the receiver side is indicated about the repetition
- When the repetition is over then a Battery ON Code (Data Stop Code) is sent to indicate the end of interleaving process followed by the normal transmission.

The Scheme of Data Interleaving



Symbols: S1, S2= Repetitive Speech Bytes
*= Speech Byte (S)
D= Data Byte (S)

State Transition Diagram for DITMC at mobile station



DITMC Advantages

As compared to the predecessor - DITV (Data Interleaving Technique in Voice Networks)

- Better channel utilization enhancement (47.32%) than DITV (43.253%).
- DITMC does not exhibit any handover.
- Lesser voice delay of 2 Bytes as compared to DITV.
- DITMC suppresses the transmission of redundant (repetitive) message codes.
- DITMC makes channel space available for additional data transmission.
- DITMC can detect much smaller duration voice pauses, which are generally more frequent.
- There is negligible inbuilt delay in this system and is insignificant for real-time applications.
- Unlike voice interpolation processes, DITMC does not make use of any voice detectors.

Increased Channels for Data

V: voice channel
I: interleaved channel available for data traffic
D: data channel

Channel Allotted to Voice & Data	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Number of data channels (due to interleaving)
Channel available for S1	V	V	V	D	D	D	V	V	V	D	D	D	D	D	V	D	9
Channel available for S2	V	V	I	D	D	D	I	V	V	D	D	D	D	D	V	D	11
Channel available for S3	V	I	I	D	D	D	V	I	I	D	D	D	D	D	V	D	13
Channel available for S4	V	I	V	D	D	D	I	I	V	D	D	D	D	D	V	D	12
Channel available for S5	V	V	V	D	D	D	V	V	V	D	D	D	D	D	V	D	09
Channel available for S6	I	I	I	D	D	D	I	I	I	D	D	D	D	D	I	D	15
Channel available for S7	V	I	I	D	D	D	I	V	I	D	D	D	D	D	I	D	14
Channel available for S8	V	V	V	D	D	D	V	V	I	D	D	D	D	D	V	D	10

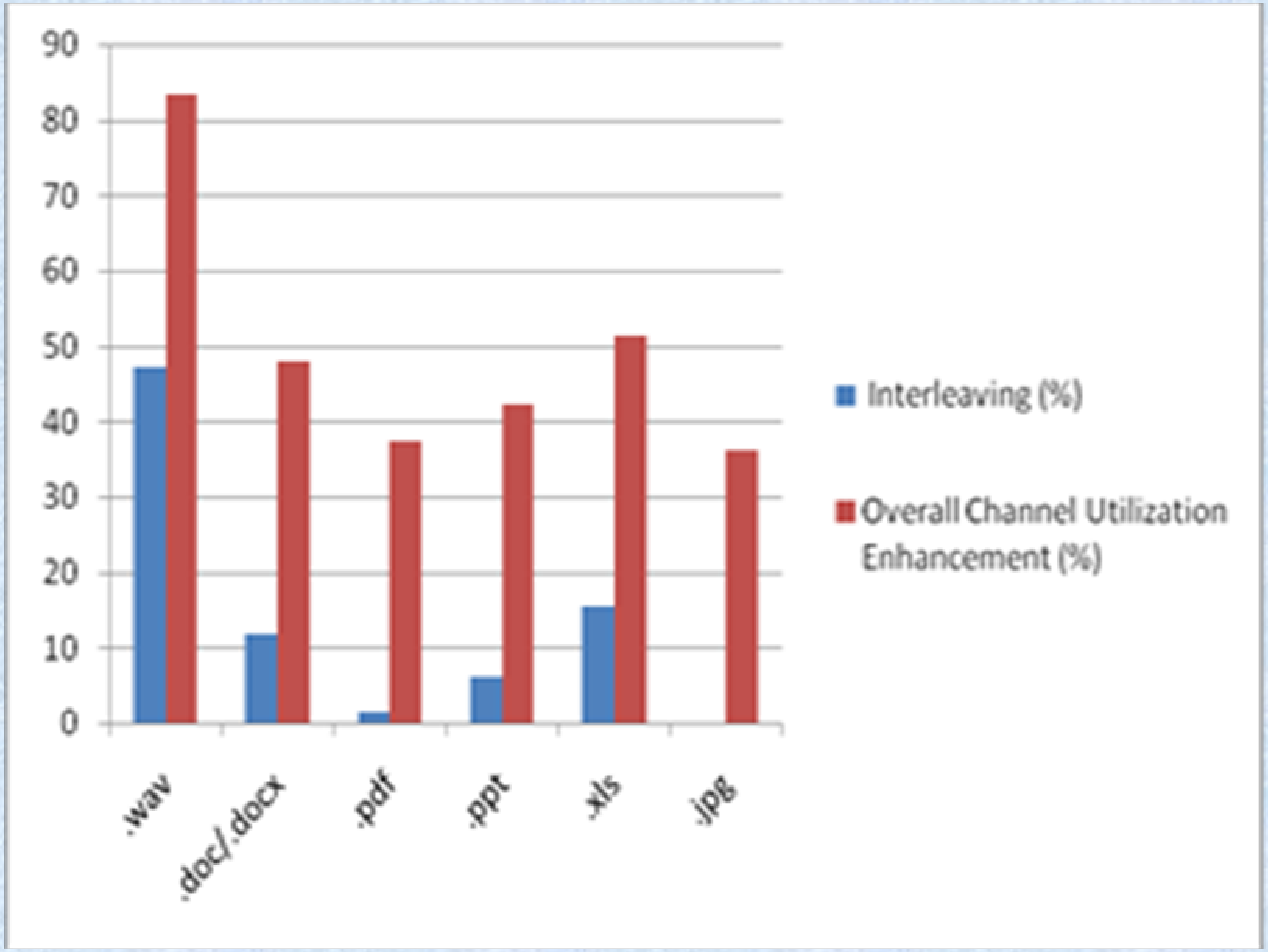
Initial Experimental Indication

Simulation experiments for GSM network settings

No: of Samples	File Type	% Interleaving	% Overhead	Overall Channel Utilization Enhancement
120	.wav	47.32	0.034	83.32%
25	.doc/.docx	11.90	1.25	47.9%
25	.pdf	1.41	0.28	37.41%
25	.ppt	6.22	1.34	42.22%
25	.xls	15.43	2.68	51.43%
25	.jpg	0.041	0.015	36.041%

Initial Experimental Indication

Graphical representation of the initial experimental results



Applying DITMC in other domains

Not only GSM/5G/LTE

- Multi-path routing when streaming data flows, e.g., multimedia in edge-centric and mobile environments.
- Active subscription control in smart spaces for effective remote detection of information update by mobile participants (subscribers).
- Supplementary processing on an edge device for information sharing in smart spaces when in addition to its primary function the target device performs data processing delegated by surrounding participants (clients).
- Selection of appropriate devices among surrounding volunteers when underutilized device can make some processing, i.e., active involvement into the system even small devices

Conclusion

- The DITMC-based methodology can be efficiently applied in reducing the traffic congestion in GSM networks and in other mobile network.
- The network transmission performance is improved (with minimum hardware complexity) to a good extent (in the order of 40%) leading to enhanced capacity in a GSM network.
- In the GSM case, our simulation experiments showed that the overall channel utilization becomes 83% from the original 36%. More development on the underlying mathematical model is needed to elaborate the “goodness of fit” property with verification within real-life scenarios.
- Development and experimental study of possible extensions of the DITMC-based methodology to other application scope form the direction of our further research.