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An Impairment Sensitive and Reliable SR-ARQ Mechanism for Unreliable Feedback in GPRS

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***Abstract*—**The advances in wireless communication have opened unlimited horizons but there are some challenges as well. The Nature derived air medium between MS (Mobile Station) and BS (Base Station) is beyond human control and produces channel impairment. The impact of the natural conditions at the air medium is the biggest issue in wireless communication. Natural conditions make reliability more cumbersome; here reliability refers to the efficient recovery of the lost or erroneous data. The SR-ARQ (Selective Repeat-Automatic Repeat Request) protocol is a de facto standard for any wireless technology at the air interface with its standard reliability features. Our focus in this research is on the reliability of the control or feedback signal of the SR-ARQ protocol. The proposed mechanism, RSR-ARQ (Reliable SR-ARQ) is an enhancement of the SR-ARQ protocol that has ensured the reliability of the control signals through channel impairment sensitive mechanism. We have modeled the system under two-state discrete time Markov Channel. The simulation results demonstrate the better recovery of the lost or erroneous data that will increase the overall system performance.

***Keywords*—**ISR-ARQ, MAA, RSR-ARQ, SAA.

I. Introduction

GENERAL packet radio service (GPRS) is an overlay in the GSM (Global System for Mobile Communication) [3] to provide data services with the efficient use of idle resources of the system. Multimedia communication is very sensitive [7] to extensive channel impairment due to hostile (air) medium at the radio link. GPRS system at the radio link has its limitations such as scarce radio resources, power [2], memory and delay [10] etc. After scanning through the protocol pile of the GPRS system, the evident root cause of the above mentioned limitations lie at the radio link. Traffic from both ways (i.e. Uplink and Downlink) is affected at this interface due to wireless propagation that causes severe jitter [9] in the system. The SR-ARQ protocol is also in operation at the radio link of the GPRS system. The mobile station (MS) and the base station (BS) are the two terminals, responsible for the exchange of information through the air interface.

In this research, we have focused on the reliability of the SR-ARQ protocol. During its operation, the SR-ARQ protocol has two types of blocks (Data blocks, Feedback or Control Blocks). Both of the sources may suffer loss or get erroneous [12] during the impairment-prone air interface. Moreover, buffering [1] of data blocks take place at both the terminals (MS and BS) to ensure sequenced delivery [6] of the blocks to the upper layers. Optimized buffering is also dependent on the efficient recovery of the erroneous data blocks. Current research in this area focuses on the delay characteristics and reliability of the data blocks but feedback blocks are equally important, as without reliable feedback, it is impossible to even consider reliable data recovery.

The SR-ARQ protocol only uses one control block, NACK (Negative Acknowledgement) as a message to either terminal (MS or BS) for the retransmission of the lost or erroneous data blocks. If NACK gets erroneous or lost because of channel impairment at the air interface, it would produce even a greater jeopardy than the loss of data block in the system. It is safe to say that an impairment sensitive and reliable feedback mechanism presented in this paper would keep the system terminals updated about the natural conditions and this exchange of information will help in the normal operation of the system.

II. Related Work

The intensive and dynamic research on the different dimensions of the SR-ARQ protocol is being carried on. Michele Zorzi in [5] found the exact statistics of the delivery delay of the SR-ARQ protocol by using two-state Discrete Time Markov Channel (DTMC). Efforts to mitigate the limitations of the two-state DTMC are made in [6] to find the delay statistics on N-state Markov Channel that result in the computational complexity. In [7], two-state DTMC is preferred again because of its simplicity to find the exact delay statistics but a new approach of packet tracking is considered to reduce the computational complexity of the system.

Delay has the strong impact on the throughput performance of the multi-rate transmission in the multi-user environment. In [4], Ekram Hossain used Finite-state Markov Channel (FSMC) to remove the weaknesses of the existing work on two-state DTMC to find the exact delay statistics and captures the multi-rate transmission with adaptive modulation and non-instantaneous feedback. However, most of the recent research is ignoring the impact of the feedback communication (i.e.

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NACK) [7] in the SR-ARQ protocol under the impaired channels.

In [12], Sook Jeon and Geon Jeong considered the erroneous feedback channel while the SR-ARQ protocol is in operation. They have presented an improved SR-ARQ (ISR-ARQ) scheme to overcome the impact of erroneous NACK. In that scheme BS is packet sender and MS is receiver. NACKs are transmitted from MS to BS on the trial (attempt) basis, where every trial has a time limit. In the first attempt, when erroneous or lost data packet is detected by the MS, the formula L^K where (L=2 and k=1, 2, 3…) is used for the increment in NACKs till either erroneous data packet is recovered or time limit for a trial is reached. However, this approach has ignored the channel impairment condition while increasing the number of NACKs and trials. This system is not only resource hungry but also consumes time during the operation.

We have enhanced this idea by keeping the number of trials (number of attempts) to minimum. The numbers of NACKs can be increased by analyzing the channel impairment conditions. Bad channel impairment conditions would increase the number of NACKs and vice versa. That is why, the presented mechanism acts in a dynamic and robust way.

III. System Model

Because of the simplicity, we have modeled our system on two-state DTMC. Packet data channel (PDCH) of the GPRS system always toggle between two states, i.e. good and bad state. The transition of two states [11] in our system can be shown as:

Current State		Future State
Good	→	Good
Good	→	Bad
Bad	→	Bad
Bad	→	Good

We considered 0 for the successful transmission and 1 for the failed transmission. The transition matrix [9] T is given as:

$$T = \begin{bmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{bmatrix} \quad (1)$$

The erroneous blocks are only produced during the bad channel conditions. Among the above transitions, we are only concerned with the absolute probability of the bad states at any specific step (time). Absolute Probability is computed by multiplying the initial vector with the transition matrix [11] of that step. This can be represented as:

$$P^n = P^{(0)}T^n \quad (2)$$

In this research, we are interested in high channel impairment condition where probability of unsuccessful blocks [9] is high (say 20%[1]). If $P_i^{(0)}$ is the probability that was initially occupied by the system then the total probability must be 1:

$$\sum_{i=1}^{m} p^{(0)} = 1 \quad (3)$$

Where m is a finite number of states and the absolute probability will be:

$$P_j^{(n)} = P^{(0)}T^{(n)} \quad (4)$$

Now, we only extract the bad state probability from the absolute probability vector. This absolute transition probability of the bad state is used as an object for finding the quantity of NACKs (feedback) required at a particular time based on channel impairment. We have used binomial distribution in which we fix **n** (the maximum number of NACKs a system should send). We compare the absolute probability of bad states in the cumulative probability column of Table I and choose the closest value. The **NoK** (Number of NACKs) of the respective row possessing the closest value of the bad state absolute probability is the required output. Input sources to binomial distribution and table structure is given as:

x → Random variable varies from 0 to n
n → Fixed number of trials defined in the system
p → Good state probability computed from initial vector
NoK → Represent the number of NACKs required for successful recovery of erroneous data block

TABLE I
NoK Calculation

NoK	**Probability b(x; n, p)** $\sum_{NoK=0}^{x} \binom{n}{x} p^x q^{n-x}$	**Cumulative Probability**
0	0.0003	0.0003
1	0.0064	0.0067
2	0.0512	0.0579
3	0.2048	0.2627
4	0.4096	0.6723
5	0.3277	1.0000

For example, our system is facing the rough conditions at the air interface having bad state probability 0.19. We compare this value in the cumulative probability column of the Table I. The corresponding NoK of the closest value 0.2627 is 3. This means that we need 3 NACKs to overcome the bad state probability of 0.19. In this way, we have mapped the quality of the channel to the probable quantity of NACKs for the successful transmission of the NACK (BS to MS) to overcome the impact of channel impairment.

IV. System Performance

The system performance at the air interface can be judged on the basis of optimized communication of control signals between two terminals (MS and BS). When communication media is beyond human control (like air medium) than the

[1] One can use different percentage for the bad state as the natural condition demands

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time is a decisive factor. Performance of the SR-ARQ protocol is also dependent on the speedy recovery of the erroneous or lost data. The SR-ARQ protocol uses one or more number of attempts to recover the data. As the number of attempts increases, consumption of the time also increases that drastically decreases the system's performance. The approach presented in [12], ISR-ARQ (explained in the Related Work) is a multiple attempt approach (MAA) in which both the number of trials and NACKs are increased without considering the channel impairment. But in our system model, single attempt approach (SAA) is followed in which we increase the number of NACKs on the basis of channel impairment conditions and keep the attempts (trials) constant.

.Now we simulate the model presented in the previous section to compare the two approaches (i.e. MAA and SAA) in MATLAB. During simulation, we have also kept the randomness and uncertainty alive which has confirmed the strength of simulation model. In a cell, any of the MS or BS can be data block sender or receiver. But we assume that MS is the data block sender and BS is receiver. It is also assumed that the transmission of NACK is always successful after the assessment of the bad state probability and the NoK. When BS detects the erroneous or lost data block, it initiates the RSR-ARQ which may generates multiple copies of NACKs but MS ignores all others except the first one.

A. Performance Analysis

The performance of the two approaches (i.e. MAA and SAA) is analyzed on the basis of the different variables. The number of attempts refers to the no of cycles between MS and BS to recover the erroneous or lost data block. Impairment is the probability of the bad channel due to rough conditions at the air interface. Block error rate (BER) is the number of erroneous or lost data blocks at a particular time step. The efficiency is the most important parameter to gauge performance of the system. The configuration of efficiency [8] is defined in equation (5) as:

$$\eta = p * m / T \tag{5}$$

Where **p** is the absolute probability of the good state, **m** is the number of data blocks in a cycle and **T** is the time to take that cycle (attempt).

In Fig. 1, the number of attempts remains constant in SAA while channel impairment is increasing. But in MAA both channel impairment and no of attempts are directly proportional to each other. SAA will increase reliability in the system. In contrast, the MAA shows instability and uncertainty which decreases reliability.

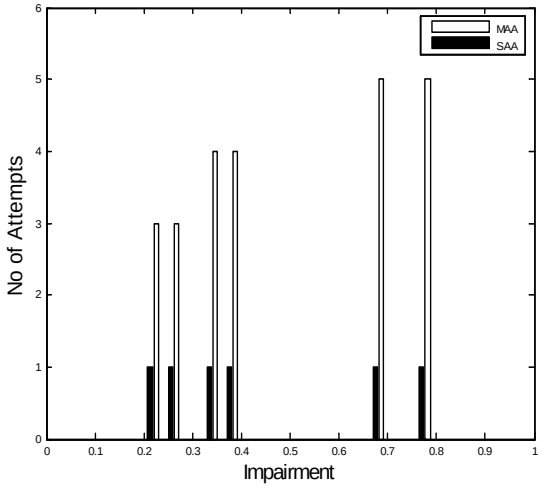


Fig. 1 Impairment vs. No of Attempts

When we compare efficiency against the number of attempts in Fig. 2, the SAA remains constant with the increase in the efficiency but in MAA efficiency is decreasing with the increasing number of attempts. The one important parameter of efficiency is T (time) and increasing time has adverse impact on the efficiency. The characteristics of no of attempts show that increasing the no of attempts decreases the efficiency. In other words, decrease in efficiency means no of attempts are increasing. As in SAA we have kept the number of attempts to unity which increases the efficiency and smooth line shows reliability.

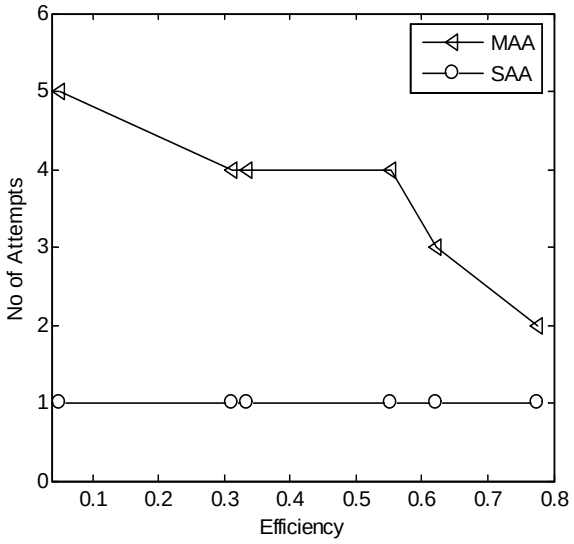


Fig. 2 Efficiency vs. No of Attempts

In Fig. 3, we evaluate efficiency against impairment in which efficiency is falling with increasing channel impairment in MAA but in SAA efficiency remains stable with the enhancing channel impairment. Impairment is increased when roughness in the natural condition is on the rise. More impairment means more time needs for the successful transmission of NACK which negatively impact on the

efficiency. The characteristic of the SAA shows the steady line even when impairment is growing because impairment is compensated with the increase in number of NACKs. Here time is kept in control which increases the efficiency and reliability.

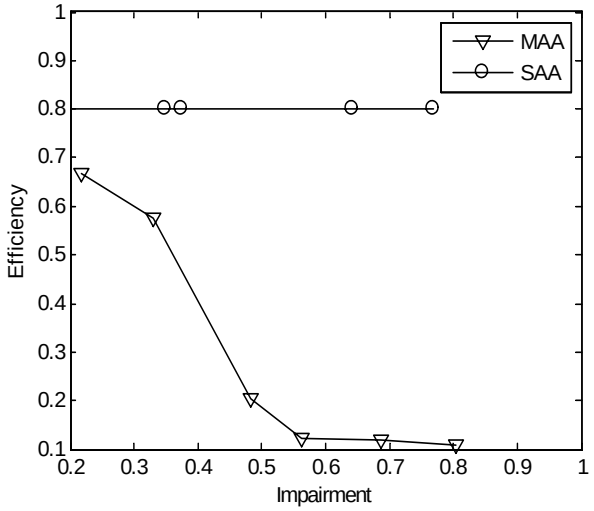


Fig. 3 Impairment vs. Efficiency

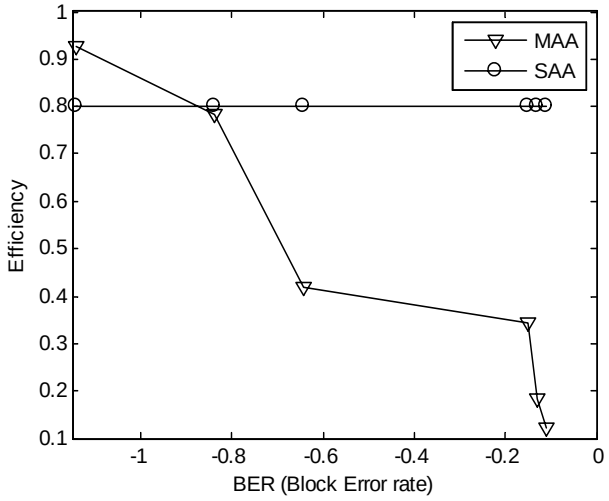


Fig. 4 $\log_{10}$ BER (Block Error Rate) vs. Efficiency

In Fig. 4, efficiency is falling with the increasing BER (Block Error Rate) in MAA but in SAA efficiency remains straight with the growing BER. The basic reason behind the increase in BER is the increase in impairment. So the successful propagation of the NACK requires more time which we are decreasing on the basis of channel impairment by increasing NACKs. Therefore the flat line of the SAA shows that increasing BER does not have much impact on the efficiency when the RSR-ARQ is in operation.

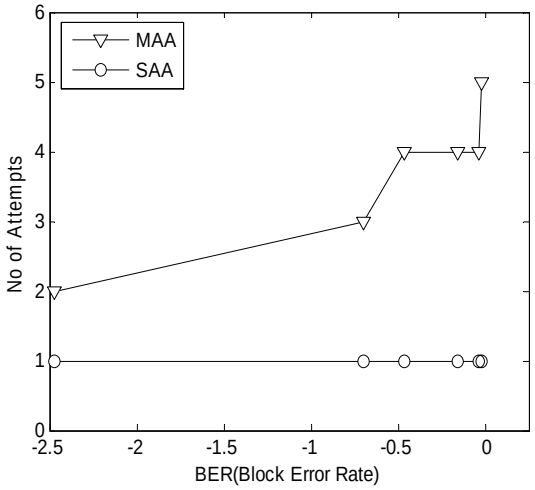


Fig. 5 $\log_{10}$ BER vs. No of Attempts

In Fig. 5, MAA and SAA are plotted against BER and No of Attempts. The SAA shows no impact of increasing BER because no of attempts remain constant after increase in NACKs on the basis of channel impairment conditions. But in MAA, increasing BER also increases no of attempts which have the bad impact not only on the reliability of the system but also on the overall system performance. Therefore even line of the SAA shows reliability and better performance.

The characteristic of the SAA shows stability which enhances the reliability in the transmission of NACK to the destination. Our analysis demonstrates that the RSR-ARQ protocol improves the reliability by absorbing the channel impairment.

V. Conclusion and Future Work

The proposed reliable SR-ARQ (RSR-ARQ) protocol is highly recommended in heavy channel impairment conditions. It is a single attempt channel impairment sensitive feedback communication mechanism, which improves reliability and system performance. The system model actually translates the quality of the channel into quantity of NACKs to increase the reliability in the feedback communication. But all that is not costless because the RSR-ARQ is resource hungry that will increase the processing load on the system. But when we relatively compare with the ISR-ARQ [12], the RSR-ARQ is impairment sensitive and more reliable.

In future, channel impairment sensitive model will be used for the decision-making at the air interface terminals to minimize the impact of channel impairment conditions. We will focus our efforts to decrease the computational complexity in the RSR-ARQ and will improve our model of the channel impairment sensitive mechanism as well.

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