Using Markov Chains Complexity Minimization with GFDM for Integrated Terrestial Communication

Ajeesh S[1], Betty Mary Jacob[2], Nisha Mohan P.M[3], Vidya Vijayan[4]

[1,2,3,4]*Assistant Professor, Dept. of computer science with Engineering, Mount Zion College of Engineering, Kerala, India*

Abstract - *This paper depicts how to minimise security models using Markov chains. The model is used where safety of a directed system is violated, so the system cause material loss. The minimization method allow to prove the rate of the event is sufficient. We also need to prove that the final design using selected redundancy technique meets dependability requirements. Integrated Satellite-Terrestrial communication system, especially the integration of satellite communication is regarded as a research hotpot. Future integrated systems are withing a more compatible with robust physical layer waveform.*

Key Words: OFDM, CDM, Terrestial

1. INTRODUCTION

The physical layer access waveform with scheme design problem. Considering the system model of integrated satellite-terrestrial communication systems, have a unified air interface. LEO satellites with multi-beam with inter satellite link can be identified as an additional access components in the integrated S-T communication by means of allowing direct with over to terrestrial radio interfaces, with roaming between satellite with terrestrial communication is seamless .[1] Single-mode mobile terminals, including withheld, vehicle-mounted, airborne with other types, can independently choose LEO satellite constellation radio access network according to the link situation. In order to meet the requirements of designing the integrated access air interface, it is necessary to evaluate the applicability of promising terrestrial physical layer access waveform with possible scheme in satellite communication.

If an event causes a situation where safety of a system is violated, it will be called difficult event. A rate of a difficult event is called difficult rate. [2]Safety models based on Markov chains are designed to calculate a difficult rate of a system. This paper presents a method of reducing safety models that allows us to reduce the models, so they contain one transition with one difficult rate only. [3]The transition corresponds to difficult event of the system.

The minimization method allows us to

1) Calculate Safety Integrity Level

2) Determine, whether the difficult event can be omitted safely. [4]

The drawback of the minimization is the loss of perfection. Perfection is not crucial in our case, but we must prove, that inaccurate difficult rate calculated from reduced model is pessimistic. [5] In other words, we must prove that the real system will be safer than the system modeled by reduced model. The proposed minimization method is used to determine difficult rate of a case study system containing two modules in this paper.

Code Division Multiple Access has been used for physical layer access technology for a long time has many advantages such as robustness in the case of low signal to-noise ratio, high capacity, good confidentiality with so on. [6]Because of these advantages CDMA is also widely used in satellite communication up to now. As technology develops, cyclic prefix orthogonal frequency division multiplex, which is much more flexible, is adopted in systems due to its ability to resist multipath interference with low complexity. 5G new radio will continue to use OFDM.[7] However, its high peak average- power ratio , sensitivity to synchronization error with high out-of-b with OOB ways decide that it is not the best choice for integrated S-T communications . More than that, we consider to employ improved OFDM technology, Generalized Frequency Division Multiplexing each subcarrier contains a number of sub symbols.

2. MINIMIZATION OF SAFETY MODELS

The minimization of the safety model is made by joining all non-difficult states into a single reduced state. Any non-renewable safety model can be reduced using this procedure to the same reduced model. [8]The difficult states correspond to each other, exact model and Reduced model are used in further calculations to distinguish among them. The reduced model also contains difficult rate Difficult that has to be calculated. [9] The minimization is valid when the main requirement is met. The main requirement is that the failure distribution function FR(t) of reduced model must be greater than the failure distribution function FE(t) of exact model all the time. [10]

The minimization is made as follows:

1) Calculate MTTF of system using Laplace transformation over the differential equation system derived from the Markov chain.[11]

2) Use MTTF to obtain estimation of difficult using equation (2) from Section II. Equation (2) can be used, because

reliability function of the reduced model has the exponential distribution. [12]

3) Calculate the failure distribution function FE(t) of the exact model.[13]

4) Make correction of Difficult to satisfy the main requirement. The correction coefficient k is used during correction. It is incremented by 0.1, but any positive increment can be used. The lower value of increment leads to more accurate result, but it increases the number of iterations.[14]

3. PURE ALOHA AND IMPROVED S-ALOHA

The simplest random access rules is ALOHA or pure ALOHA. The principle of this rules is very simple. When a user wants to send a packet, he does not need to care about whether the channel is idle or not. Surely, due to the random transmission of data packets by users, when the transmission time of several users overlaps, data packets of different users will run into each other, and the data packets need to be retransmitted after waiting for a random period. [15] In this paper, the sum of newly generated data and retransmitted data per unit time is defined as system load G. Throughput is defined as the total number of data successfully transmitted to the BS per unit of time S. The probability of data packet successfully access to the BS is called the access success ratio P, P is equal to S / G. The average time interval from the generation of the packet to the successful transmission to the BS is called the packet average delay. [16]The main defect of the pure ALOHA rules is the low success ratio of random access. The system throughput is constrained whether load is heavy, because individual user transmission is completely random. [17]Too many times of collisions and retransmissions result in a large waste of channel resources. So as to reduce the collision, time slot ALOHA is proposed.[18]

Compared to pure ALOHA, the S-ALOHA rules allows packets to be sent only at a specific time. The channel is divided into time slots whose starting time is the same for all users (so all users must be synchronized). [19]

The Two-out-of-two system (2oo2) is a system containing two independent functional parts that meets the following requirements:

• The safety of the system cannot be violated by a single fault in the system. [20]

• Two faults will never occur in the system at the same time. [21]

• Assuming a fault occurs in one module, the redundant module is able to lock the system into a safe state, so that a possible future fault will not cause a difficult state. Safe state is considered as the situation where the system is not operational, but the safety is not violated (e.g. all lights are red and traffic is operated by human operator). [22]

• If the second fault occurs before the redundant module locks the system, the safety of the system may be violated. This double-fault situation is considered as the difficult state. [23]

The double fault rate of the Two-out-of-two system is per hour, so the system with parameters presented in Section IV-D does not meet Safety Integrity Level 4. A double fault must be taken into account in this case, but the reduced model can be used when the complex system built from Two-out-of-two modules is created. [24]

The double fault rate may be decreased using additional redundancy, so a double fault might be neglected in such complex system safely. The rate of a double fault of such complex system can be calculated by Fault Tree Analysis or hierarchical models. [25]The minimization procedure will be improved to support multi-difficult systems. The multi-difficult system can fail in more than one way (e.g. a diode that may be opened or shorted). Different failure types may cause the different behaviour of the system, so they cannot be merged. This improvement will allow us to create the detailed models of large complex systems and to simplify them safely in accordance with Czech and European standards.

Among all the random access methods studied above, owing to the randomness of access methods, the system throughput and average delay performance are relatively poor, which are common shortcomings of various random access technologies. Although the throughput and average delay performance of ALOHA system are improved because of the introduction of the time slot, the system performance is still relatively poor under heavy load. Therefore, in this paper, S-ALOHA technology is introduced into SS-GFDM schemes, which can not only retain the simple structure of GFDM and easy operation property of ALOHA system, but also improve the access performance.

To sum up, the combination of GFDM and CDMA can solve the problem of performance degradation caused by low SNR environment and high PAPR property of traditional GFDM. At the same time, multiple sub symbols of GFDM and multiple PN codes of CDAM can effectively reduce the probability of packet collision in S-ALOHA. [26]Also it will increase the capacity of access waveform. All advantages mentioned above is beneficial to hybrid S-T communication system Due to the introduction of multi-code spread spectrum technology, the probability of packet collision and retransmission is low, so the less cost on the path when the data is successfully transmitted. However, it is obvious that the length of the spreading code limits the number of spreading codes, while an excessively long spreading code increases the transmission delay. [27]Therefore, it is necessary to weigh the number and length of the spreading code. In order to solve the problem of large capacity access in low SNR environment for hybrid S-T communication system, this paper proposes a new kind of physical layer access waveform-spread spectrum GFDM. After over viewing

GFDM systems, the implementation of improved GFDM-CDMA is elaborated in detail. Two kinds of SS-GFDM, GFDMCCSK and GFDM-DSSS are discussed and compared.

What's more, S-ALOHA rules is introduced to solve the large capacity random access problem in integrated S-T communications. The simulation and analysis results prove that the proposed scheme is more effective than conventional GFDM scheme in AWGN and frequency selective fading satellite channel.[28] The PAPR performance of proposed GFDM-CCSK waveform is obviously improved compared with traditional OFDM and GFDM. Meanwhile the multi-code GFDMCCSK can effectively increase the access success ratio and reduce the average delay of system. In summary, proposed GFDM-CCSKCDMA schemes is a potential physical layer access for future integrated S-T communication system. The proposed access waveform is especially suitable satellite-terrestrial mMTC or IoT system with wide area coverage.

The proposed method of minimization of safety models based on Markov chains can be used to calculate difficult rate – rate of difficult event that will lead to situation situations where safety of a system is violated. The minimization is intended for any safety model – absorbing Markov chain satisfying the conditions mentioned in Section II. The estimation is especially useful when it allows us to prove that the difficult rate of a system is low enough to meet Safety Integrity Level requirements, so difficult event may be neglected in the further models and calculations. The difficult rates of reduced models are also useable in hierarchical safety models that are currently developed at our department.

3. CONCLUSION

Hierarchical models use multiple linked models to reflect a structure of a system. Multi-level hierarchy may be used to describe multiple level of redundancy independently and to decompose one safety model of a complex system into multiple smaller models. The minimization is used to estimate the rate of a double fault in the Two-out-of-two system that is used as the safety model of the railway station signalling and interlocking equipments.

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