An Access Protocol for Mobile Satellite Users with reduced Link Margins and Contention Propability (Extended Abstract)

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Abstract

German Aerospace Agency (DLR), Fraunhofer FOKUS.cats, and Tesat-Spacecom have designed a future multimedia ATM-based LEO satellite network. Part of the development was an adaptive MAC and FEC scheme which are presented in this paper. The MAC protocol reduces contention while the FEC scheme guarantees a maximum ATM cell error rate of 10^{-6} even in the presence of rain. FEC and MAC were implemented in a prototype which was finally used to conduct measurements evolving some fundamental results for the design of future, satellite based, multimedia communication systems. These learned lessons concern the impact of shadowing, rain attenuation, and TCP's maturety when being used over variable propagation delay links.

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I. Protocol Design

The design of the of a MAC layer for an ATM-based NGSO satellite network, inherently supporting different QoS classes, was influenced by several constrains deriving from the satellite constellation and ATM itself, e.g.:

- variable propagation delays,
- swiftly changing channel error rates due to the variable elevation angle and rain attenuation, and
- the severe impact of shadowing due to the vehicular's movement.

The MAC layer handles these problems by an adaptive frame structure and an adaptive FEC scheme.

The adaptive frame structure consists of duplexed FDD-TDMA frames of a fixed duration of 24 ms. The up-link frame is devided into a *reservation area* and a *contention area* where the boundary between the two may be changed for each frame in order to reduce contention. The former area is used for UBR and CBR traffic while the latter is used for initial connection set-up. Each down-link frame starts with a *burst transmission plan* for the next up-link frame.

The adaptive FEC scheme focues on rain effects as due to the usage of directional antennas, multipath fading is slight [1] and shadowing due to obstacles cannot be compensated by FEC. The FEC scheme may on the fly change between mere 16 QAM to the mostly deploied 4 QPSK and from a simple CRCs to RS(65,53) and a rate $1/2$ block turbo code while still preserving a fixes useful data rate by adapting the MAC packet lengths. This FEC scheme guarantees a link availability of 99.14% with a CER-threshold of 10^{-6} while reducing the link margin to a minimum for the specified LEO satellite network. [2]

This adaptive frame format and FEC scheme is benivicial esp. for mobile users as they are either located in different regions with different attenuation or move to regions with different channel characteristics (fast moving trains crossing a thunderstorm).

II. Protocol Implementation and Tests

The designed protocol is (partially) implemented using the FreeBSD–5.0–current version [3] for testing and demonstration purposes. The implementation is modular in terms of separating a satellite channel emulation entity from the implementation of the MAC protocol and from the end-system itself. Therefore it is possible to run tests over various satellite constellations[1] besides the original LEO target system.

[1]In fact, the same environment is currently used to evaluate connecting the ISS' Columbus module via ATM to Earth.

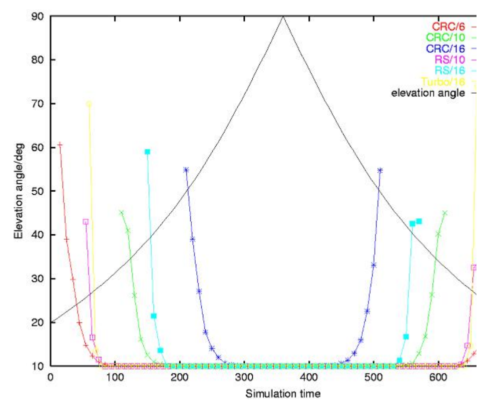

Fig. 1. Measured Error Rates for Various Codings and Rain Intensities

Additionally, each possible end-system type with an appropriate network interface (e.g. Windows-PCs or Solaris based workstations) may be connected via the new MAC. Shadowing effects due to mobile user's movements are represented by a on-off-modell; the transition propability is based on real-world measurements conducted by DLR.

Conducted measurements and tests included but were not limited to:

- Measuring the effects of the different FEC schemes for various rain intensities,
- Effects of shadowing to mobile users, and
- Usability of standard TCP in a variable delay, mobile user environment.

Figure 1 shows the measured error rates for various coding schemes (CRC, RS, and Turbo) and rain intensities (6, 10, and 16 mm/h) and highlights the advantage of selecting an appropriate FEC scheme for each mobile user individually.

While the link's degregation due to rain effects may be overpassed with the FEC schmes most of the time, the impact of shadowing on mobile users, esp. in an urban environment, is dramatic. Figure 2 depicts the cell loss ratio and cell delay for a pedestrian; the queue size and cell dropping policies are already optimized due to former measurement results. Retention period histograms show a concentration in between 10 and 60 seconds. These periods are long enough to let the

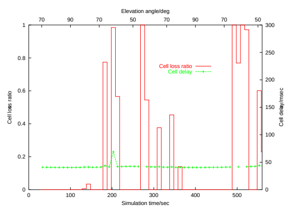

Fig. 2. Cell loss and delay caused by shadowing due to pedestrian's movements

ATM signaling fail.

Due to the analysis of shadowing effects, TCP experiments were conducted with non-moving users. The main concern was to verify previously conducted simulations which analyzed TCP's ability to cope with the variable transmission delay due to the LEO satellite consellation [4], [5]. Experiments showed that TCP connections over the deloped satellite system is well able to reflect the variable transmission delay without triggering premature retransmissions. Even though, the standard TCP implementation of FreeBSD [3] was used, several kernel flags were adapted to achieve optimal performance (e.g.: Timer Granularity and Buffer Sizes).

III. Conclusion

The paper presented a new adaptive MAC protocol in conjunction with an adaptive FEC scheme which reduce both, possible contention and unnecessary link margings while still guaranteeing a high link availebility. Tests of the prototype implementation showed that the considered satellite systems is well able to guarantee a mobile, high quality multimedia communiction for mobile users even though for urban areas the need for terrestrial support (e.g. by ground-based repeaters or roaming with other networks) is inherent.

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