Integration of Multicast and Unicast for Highly Efficient Video Delivery in Cellular Networks

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Context

Video is one of the most popular services in cellular networks and an important factor of the load of these networks. In 2019, videos are mainly transferred in unicast mode. This means that when a video is very popular the same content is transmitted as many times as the users request them. With evolved Multimedia Broadcast Multicast Service (eMBMS), a video file can be transmitted at the same time to a set of terminals on a given area. Both modes have their advantages: thanks to the feedback channel and the link adaptation mechanism that is activated in 4G networks, each unicast link is reliable and optimized; eMBMS takes benefit from the transmission diversity but reliability cannot be guaranteed.

Using LTE as a broadcast technique is recognized as an important issue for 4G and 5G. The third generation Partnership Project (3GPP) recently specified further-evolved MBMS (feMBMS), also known as LTE Broadcast, which enables high-power transmission from high-tower sites in downlink-only mode to smartphones and media tablets while using full signal bandwidth for multicast/broadcast applications.

Up to now, unicast and multicast/broadcast have been mainly seen as independent modes. With the Multicast-On-Demand feature (MOOD), which is now available in eMBMS, it is possible to switch from a unicast transmission to a multicast/broadcast mode. First, there are no general rules to determine which mode is the best one for a given load. Second, the two modes are still seen as antagonist transmission types. The general objective of the thesis is to analyze the performance of each mode (unicast and multicast/broadcast) and to study how to combine them in a really hybrid mode in order to maximize the quality of service while limiting the radio resource that is used.

Problems

From a technical perspective, the first problem is to determine in which conditions (density of the terminals, location of the terminals in the cell, popularity of the video,…) a mode (e.g. unicast) is better than the other (e.g. multicast). Stochastic geometry has been proved to be a tool useful for the performance analysis of cellular networks and IoT systems [SLN17]. It can be reused to identify the best mode from a statistical point of view. The analysis can be completed by simulations.

The second problem is to study and develop proposals for enhancing eMBMS in the 5G cellular networks. The objective is to keep the benefits of broadcast for massive distribution of the same content (one transmission for several recipients and transmission macro-diversity) and to combine them with dynamic adaptation (including dynamic modification of the modulation and coding scheme) and Multicast Hybrid

Automatic Repeat reQuest protocols (HARQ) thanks to a feedback channel. The real-time flow repair protocol proposed in [ALP15] can be a first approach. However, in order to avoid ACK/NACK explosion, it should be improved. A first extension is to adopt a probabilistic approach for the feedback channel.

Mobile technologies are now intensively used anywhere and at any-time. This means that the environment of a terminal may be very variable: high-definition television connected to a fixed antenna on the roof of a house, smart-phone inside a building, handheld television in a car, etc. This implies very different radio link budgets. The perceived quality of service for videos depends not only on the link budget and the transmission mechanisms (physical and MAC layers) but also on the whole protocol stack, especially the transport layer (RTP, DASH). Furthermore, the key indicators are not the same for all the services: streaming can tolerate a large delay why real time television has strict latency constraints. To evaluate and optimize the different transmission mechanisms, it is thus necessary to adopt a cross-layer approach.

Required skills of the candidate

- excellent background in networks, especially low layers (physical layer, MAC layer, cellular networks)
- good basis on digital communications (digital modulation, baseband transmission,…)
- background in mathematics (probability, optimisation, integral)
- capacity of reading technical specifications and of extracting the underlying concepts
- and the traditional skills for a thesis (imagination, precision, tenacity, listening ability, team spirit)

References

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