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Towards more efficient wireless Networks

RICO SCHWENDENER AND CHRISTIAN FISCHER **We have all experienced that mobile communication over a wireless network is less reliable than using the wired network. During the past few years, a new concept to improve the throughput in wireless networks has become important. The key idea behind the approach is to adaptively manage wireless resources depending on the current state of the wireless links (cross-layer interaction). A well-known example is link adaptation in UMTS/HSDPA (High Speed Downlink Packet Access).**

There are many possibilities to introduce cross-layer interaction in wireless networks, i.e. any protocol layer that is responsible for access or resource allocation decisions (e.g. scheduling, error protection, routing, and flow control) could be involved. In this article, we specifically address concepts where the physical layer knowledge of the wireless channel is shared with higher layers to optimise resource allocation.

We can distinguish different kinds of channel variations due to mobility (e. g. velocity v~1 m/s in the ISM band around f~2.4 GHz). If the channel attenuation is changing on a small time scale, i.e. within a few milliseconds, this is called short-term fading. The effect is caused by multipath propagation with constructive or destructive interference between two or more impinging waves. A second effect is long term fading, which is caused by location dependent effects like shadowing and interference. Here the fluctuations are rather in the range of seconds or longer. The time scale of the channel variations has a strong impact on the feasibility of a cross-layer approach. For example, it is not appropriate to schedule the transmission of a packet according to the channel quality, if channel conditions stay poor over several seconds and the packet belongs to a real time service. Therefore a cross-layer approach needs to consider the actual channel conditions as well as the requirements of the traffic.

In order to show the potential of a cross-layer approach in terms of throughput optimisation we consider a simple, illustrative model of a channel state dependent scheduler. It serves as an example for a cross-layer approach between the two lowest protocol layers.

We assume that there are always packets arriving from the Internet which need to be forwarded to three mobile users. For this purpose the packets are first stored in buffers at the base station. Then the transmission is coordinated by a scheduler, taking into account the state of the links for the different users. In figure1 the setup for three users is shown.

It is assumed, for this simple example, that the wireless links for the three users are independent and they are either in a good state or in a poor state with equal probability [P(good) = P(poor) = 1/2]. If a link is in the good state a packet can be transmitted successfully, in the poor state an error occurs and the packet is lost. How much influence on the throughput of error-free packets can be expected by a channel state dependent scheduling approach? We compare the performance with a round-robin scheduler. For the round-robin scheduler every user gets 1/3 of the system capacity, independent of the actual channel condition. Due to errors, only 1/6 of the system capacity can be used by a single user without errors. On the other hand, with a channel state dependent scheduler, errors only occur if all links are in a bad state. Therefore, the throughput per user is 7/24 of system capacity which is quite close to 1/3 of system capacity in an error-free system. This shows the high potential of a channel state dependent scheduler. Such a gain is also called *multiuser diversity* gain.

The importance of cross-layer concepts has recently been noticed and several standardisation groups include such approaches in their activities. For instance, the 3G Partnership Project (3GPP) proposed an enhanced high speed downlink packet access (HSDPA) with hybrid Automatic Repeat Request (ARQ) as an extension for the UMTS standard. Also the high data rate extension of the American CDMA2000 standard (1 x EV) has been designed with cross-layer concepts in mind. The ongoing activities in the standardisation of Mobile Broadband Wireless Access (MBWA) in the IEEE 802.20 workgroup will also include cross-layer concepts. Details about a few approaches are provided in the following sections.

Cross-layer Concepts in GSM-EDGE

EDGE (Enhanced Data rates for Global Evolution) is an evolutionary step from GSM towards 3G systems. Specifically, it addresses the need for higher data rates on the currently existing networks by introducing a new physical layer without modifying the services themselves. EDGE comes in two flavours, based either on GPRS (General Packet Radio Service) in the form of Enhanced GPRS (EGPRS) or on top of circuit-switched data as Enhanced Circuit-switched Data (ECSD). Here, we limit ourselves to EGPRS, the far more important and popular of the two.

EGPRS is an add-on to GPRS, limited to changes in modulation and coding. The changes are hence limited to base stations and terminals; modifications in the core network are not needed. The advantage of this is clearly cheaper and simpler introduction of the new services if GPRS is already supported.

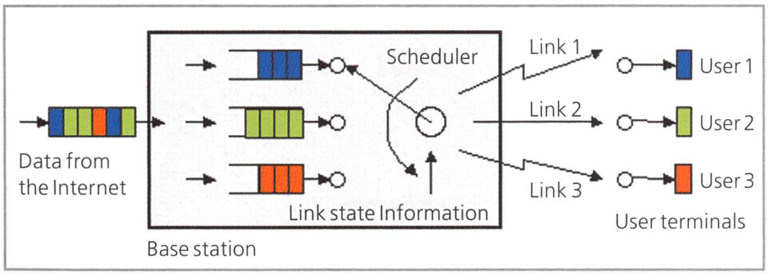


Fig. 1. Example setup for channel state dependent scheduling.

EDGE achieves higher data rates (up to about 384 kbit/s) by changing the standard GMSK (Gaussian Minimum Shift Keying) modulation in GPRS to an 8 PSK (Phase Shift Keying) modulation, therefore increasing the rate by up to a factor of three.

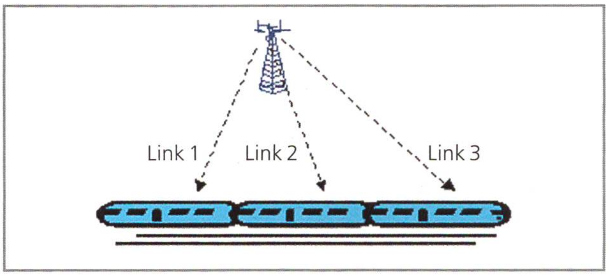
Link Adaptation

Link adaptation in EDGE is a typical cross-layer approach. The state of the channel is used to determine the correct coding and modulation to be applied. A couple of improvements have been made over GPRS, leading to better overall performance in most cases. The benefit of EDGE, and therefore of the cross-layer approach, can most easily be shown by comparing it with GSM/GPRS.

As in GSM, the channel must be measured for carrier strength, bit error rates etc. for GPRS. These operations are time consuming; however, this is of no great importance since for the transmission of speech the same coding is used all the time.

In a packet-switched environment, the coding of the data needs to be adapted to the changing environment with a much higher frequency. However, GPRS measures the channel only during idle bursts and is limited to a new channel estimate every 240 ms, making the correct coding choice a challenge. In EGPRS/EDGE, the channel measurements are taken at every burst from the physical layer equalizer. Since a measurement is made for every burst, the channel state information thus passed on is a fairly accurate reflection on the current Signal to Noise Ratio, SNR. Given these measurements, the coding algorithm can then make an informed choice about the coding scheme to use for the next radio block. The effect is that the employed coding can be adjusted to the environment at a much higher rate, thereby increasing the reliability of data transmission significantly. In conjunction with the link adaptation itself a further change has been made by permitting the packets to be re-segmented. In GPRS, re-segmentation is not possible, i.e. if a packet is lost, it needs to be retransmitted with the same coding applied to it, even if the radio environment has changed in the meantime. EGPRS/EDGE, on the other hand, has the capability to retransmit a packet with a more robust coding scheme than used for the initial transmission. On top of this, the EDGE receiver implements a soft-combining receiver structure that allows combining a transmission with a previously received, faulty, transmission to increase the chance of correct decoding in an incremental fashion. Further information on EDGE can be found in [1].

Fig. 2. Cross-layer scenario – WLAN in trains.



Cross-layer Concepts in UMTS/WCDMA – HSDPA

High Speed Downlink Packet Access (HSDPA) is to UMTS what EDGE is to GSM: a specification to increase user data rates and quality of service and generally to improve the spectral efficiency. HSDPA is designed to exist on UMTS as specified in the 3GPP Release 5 and offers theoretical data rates of over 10 Mbit/s and in practice more than 2 Mbit/s.

HSDPA introduces adaptive coding and modulation and a hybrid ARQ protocol, based on an incremental redundancy approach similar to EDGE. Equally, the data rate is adjusted in a manner to reflect the radio environment. The packet scheduling has been moved into the Node B (base station) where channel quality measurements are readily available. The scheduler then schedules the traffic among the users based on the available link quality.

There are two major new functional blocks in HSDPA: A new transport channel named "High-Speed Downlink Shared Channel" or HS-DSCH and the associated block for the MAC layer, the MAC-hs that deals for example with the scheduling.

In UMTS, the link adaptation, i.e. the adaptation of the coding and modulation on the radio link, are normally performed via fast power control only. This is to say, the power is allocated among the channels in a way to optimise overall performance. In contrast, HS-DSCH holds the transmission power constant and uses adaptive modulation and coding to account for changing environmental conditions.

The packet scheduling in the MAC-hs is performed at the base station to reduce latency. A popular scheduling mechanism is proportional fair scheduling. With this type of scheduler, the serve order is determined by the highest instantaneous relative channel quality, i.e. the scheduler attempts to track the channel state variation. Since the selection is based on relative measures (with respect to each user/channel), every user still gets a fair share of access to the channel. It is claimed that such an approach can increase system capacity by 50%. More details on HSDPA can be found in [2].

Cross-Layer Scenarios and expected Impact

As a basis for the discussion of the impact of cross-layer concepts, it is necessary to discuss the technical prerequisites and the benefits for cross-layer approaches. We can then define some scenarios that allow getting the most profit in terms of throughput enhancement. And finally, service classes which can be supported by a channel state dependent scheduler are introduced.

As mentioned before, an important goal of cross-layer interaction is an enhancement of the throughput of error-

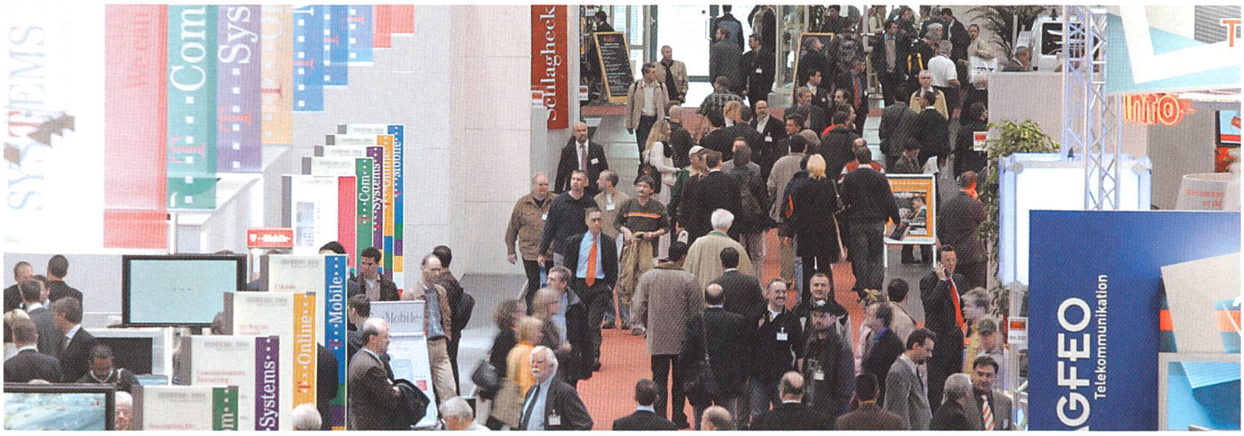


Fig. 3. Cross-layer scenario – conference/exhibition

free data in the network. On the MAC layer this can be achieved by a channel state dependent scheduler that distributes channel access times centrally. Other approaches are based on a distributed random access, where every node controls the access, based on local channel state estimates (see [3]).

Cross-layer concepts provide not only benefits, they also cause secondary effects. For adaptive scheduling, the throughput gain is at the expense of additional delay and higher delay variation due to the queuing of packets during periods of bad channel quality. Of course, such delays need to be limited by a fair scheduler by assigning resources to stations with long-term bad channel quality. In the case of adaptive rate techniques, more bandwidth is used while the channel is in a bad state. This is caused by less efficient modulation schemes with fewer bits per symbol and larger coding overheads.

There are some prerequisites for a successful exploitation of multi-user diversity. In order to achieve multi-user diversity gain, resulting in a higher throughput, it is necessary for the channel to be time variant. A channel is time variant if either the nodes are mobile or there is mobility in the environment.

The mentioned benefits and implications lead to some scenarios where cross-layer concepts potentially have a high impact. Cellular networks with mobile clients are obviously a good example. Due to the high mobility of trains, this might also be an interesting application (figure 2). One scenario would be that every wagon is fed by a mobile link and the terminals in the train are served by a WLAN access point in the wagon. In this case, every wagon link is time variant and contributes to the multi-user diversity.

There will be little benefit of channel state dependent scheduling for lightly loaded networks because throughput will not be a limiting factor. Therefore, it makes sense to deploy cross-layer optimised networks in places where a larger number of concurrent users with high bandwidth applications will be present. An example could be a large event like an exhibition or a conference (figure 3) where many people are walking around (time variant channels) and everybody likes to synchronize their emails (high load). Not all service classes allow a throughput increase by channel state dependent scheduling since additional delay and delay variation need to be acceptable. The mean time a mobile node stays in a deep fade is in the range of 125 ms, which corresponds to the coherence time of the channel for a node velocity of $v \sim 1$ m/s and a transmission in the 2.4 GHz band. Due to high delays and high delay variation, a channel state dependent scheduling approach is not feasible for real-time services. In fact, there exists a relationship between the throughput gain and the delay. If the acceptable delay is high, then the achievable throughput gain is high as well. Typical applications that can benefit most are best effort data services.

Conclusions and Outlook

With the introduction of cross-layer concepts, such as channel state dependent scheduling, an old paradigm in wireless communications has changed. It is no longer necessary to have constantly good link conditions in order to achieve a high throughput in a wireless network. Strong fluctuations of the link quality lead to opportunities of temporarily very good links. If terminals share a common medium, the probability is high that at least one of them experiences good link quality at any given instance in time.

A survey shows that many ongoing standardisation efforts include cross-layer approaches. Therefore, it can be expected that products will appear on the market in the near future that provide channel adaptive algorithms. This will be an opportunity for the suppliers to differentiate their products from the competitors. For an operator, the knowledge about cross-layer concepts enables an optimised tuning of relevant network parameters and a targeted deployment of the technology. ■

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References

[1] EDGE – Introduction of high-speed data in GSM/GPRS networks, Ericsson White Paper, available at www.ericsson.com/products/white_papers_pdf/edge_wp_technical.pdf

[2] ETSI TS 125 308, "UTRA High Speed Downlink Packet Access; Overall Description; Stage 2", Rel. 6

[3] X. Qin and R. Berry, "Exploiting Multiuser Diversity for Medium Access Control in Wireless Networks", Proc. of Infocom 2003, Apr. 2003