EURASIP Journal on Applied Signal Processing 2004:5, 772–782


# Multiple ARQ Processes for MIMO Systems

**Haitao Zheng**

*Wireless Research Laboratory, Lucent Technologies, 791 Holmdel-Keyport Road, Holmdel, NJ 07733, USA*
*Email: haitaoz@lucent.com*

**Angel Lozano**

*Wireless Research Laboratory, Lucent Technologies, 791 Holmdel-Keyport Road, Holmdel, NJ 07733, USA*
*Email: aloz@lucent.com*

**Mohamed Haleem**

*Wireless Research Laboratory, Lucent Technologies, 791 Holmdel-Keyport Road, Holmdel, NJ 07733, USA*
*Email: haleem@lucent.com*

*Received 4 December 2002; Revised 19 August 2003*

We propose a new automatic repeat request (ARQ) scheme for MIMO systems with multiple transmit and receive antennas. The substreams emitted from various transmit antennas encounter distinct propagation channels and thus have different error statistics. When per-antenna encoders are used, separating ARQ processes among the substreams results in a throughput improvement. Moreover, it facilitates the interference cancellation in certain MIMO techniques. Quantitative results from UMTS simulations demonstrate that the proposed multiple ARQ structure yields more than 30% gain in link throughput.

**Keywords and phrases:** MIMO systems, automatic repeat request, throughput, wireless communication, UMTS.

## 1. INTRODUCTION

Third-generation cellular systems are being designed to support high-speed packet data services. In the downlink, which has more stringent requirements in many of such services, high-speed packet access is provided through a shared channel where time-division multiplexing is used. Time slots are assigned to users at specific data rates through a scheduling algorithm based on the user data backlog and on channel quality indication (CQI) received via a feedback channel.[1] Such a transmission scheme allows multiple users to share the system resources efficiently by adapting to traffic and channel variations and it also avoids possible resource limitations that might occur if each user were allocated a dedicated code-multiplexed channel. Therefore, it has the potential to improve the capacity for delay-tolerant bursty services. Examples where this scheme will be implemented include the CDMA 1x EV-DO and 1x EV-DV and the UMTS high-speed downlink packet access (HSDPA) [1, 2]. Several advanced technologies are employed in high-speed downlink transmission to improve link throughput or reduce packet delay by adapting to the time-varying channel conditions, traffic statistics, and quality-of-service requirements. Some of these adaptive techniques, relevant to this paper, are summarized below.

*Multiple transmit and receive antennas.* The use of multiple antennas at each base station sector is already part of every third-generation standard. In the downlink, specifically, these antennas can be used to provide transmit diversity and/or to direct a beam towards the intended terminal. The deployment of multiple receive antennas at data terminals is also being considered. The combination of multiple transmit and receive antennas will enable the implementation of a number of multiple-input multiple-output (MIMO) techniques that promise spectacular increases in throughput without the need for additional power or bandwidth [3, 4, 5].

*Dynamic link adaptation through adaptive modulation and coding.* Typically, each transmission in the downlink shared channel is at the maximum available power, with no power control. Therefore, link adaptation [6, 7], which adjusts the modulation and coding schemes (MCS), provides an efficient way of maximizing the instantaneous usage of the wireless channel. Specifically, it enables the use of aggressive MCSs when channel conditions are favorable while it reverts to MCSs that are more robust but with lower transmission rates when channel conditions degrade. The base station

[1]Each terminal measures its channel condition and translates it into a metric to be fed back to the serving base station.

selects the appropriate MCS based on the CQI for the user served at each time slot. We hereby refer to the MCS selection process as the mapping design.

*Automatic repeat request (ARQ) or hybrid ARQ (HARQ)*. The performance of MCS-based link adaptation largely depends on the accuracy of the CQI, which is difficult to maintain as velocity increases. The delay tolerance of many data services enables the use of retransmission schemes to recover erroneous packets. Recently, HARQ techniques have been adopted by several wireless standardization bodies, for example, 3GPP and 3GPP2. HARQ [8, 9, 10] can improve throughput performance, compensate for link adaptation errors, and provide a finer granularity in the rates effectively pushed through the channel. Upon detecting a transmission failure, mostly by cyclic redundancy check (CRC), the terminal sends a request to the base station for retransmission. The delay due to packet acknowledgement can be significantly reduced by placing the HARQ functionality in the base station (Node B in UMTS) rather than in the radio network controller (RNC in UMTS). The packet decoder at the mobile combines the soft information of the original transmission with those of the subsequent retransmissions. The combined signal has higher probability of successful decoding. In general, there are two ways of soft combining. With *chase combining*, the base station repeatedly sends the same packet and the receiver aggregates the energy from the (re)transmissions to improve the signal-to-noise ratio (SNR) [11, 12]. A more sophisticated HARQ mechanism, named *incremental redundancy* (IR), transmits additional redundant information in each retransmission and gradually reduces the coding rate until successful decoding occurs [13, 14, 15]. Compared with chase combining, IR requires larger receiver buffers but it can achieve better performance [16]. It also provides finer granularity in the encoded rates and allows for better adaptation to channel variations.

*Scheduler*. In a multiuser system where user channel conditions change over time, a scheduler can exploit those channel variations by giving certain priority to the users with transitorily better channels. The scheduler critically impacts the system performance. Several scheduling algorithms have been proposed in the literature to maximize the packet data throughput, subject to various fairness conditions [17].

The above technologies are tightly coupled. However, since some of them reside in different layers, that is, HARQ in the medium access control (MAC) layer and MIMO in the physical layer, they are usually discussed and treated separately. The evaluation of each technology fails to take into account the performance improvement or degradation brought about by the other one. In particular, the link layer performance of any MIMO algorithm is usually selected according to the raw data rate at some operating point, for example, 10% packet error rate. However, when some level of channel uncertainty exists and the system supports HARQ, it may be beneficial to transmit aggressively at higher packet error rates and recover channel errors through retransmissions [18]. The throughput depends heavily on the transmission strategy. An overly aggressive transmission could produce too many unsuccessful packet transmissions that diminish the overall throughput, while an overly conservative one fails to fully utilize the channel. In this case, the overall throughput depends on the algorithms at both layers and only cross-layer design can enable the most efficient use of the channel.

In this paper, we address some of the key design issues associated with the choice of the HARQ structure to be used for MIMO physical layer transmission. We propose a new HARQ structure that matches the layered structure of the most popular MIMO architectures [19]. Simulation results show that the performance sensitivity to the choice of HARQ depends on the aggressiveness of the transmissions and on the type of CQI.

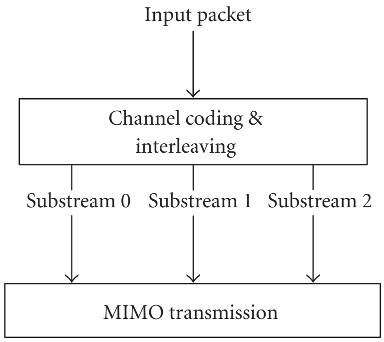
The paper is organized as follows. In Section 2, we describe the layered architectures with per-antenna encoding. Modifications to the conventional HARQ structure to fit these layered architectures are discussed in Section 3. We compare the performance of different HARQ structures in Section 4. Conclusions are drawn in Section 5.

## 2. LAYERED ARCHITECTURES WITH PER-ANTENNA ENCODING

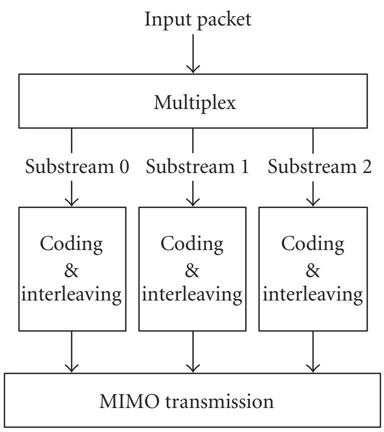
In order to approach the MIMO channel capacity in rich multipath environments, the substreams radiated from the various transmit antennas should be uncorrelated [20, 21]. Nonetheless, it may in practice be advantageous to jointly encode them (Figure 1a). This has motivated a blossoming interest in the design of space-time (vector) codes [22]. Clearly, when the substreams are jointly encoded, they should share a single CRC.

The complexity of joint detection, however, explodes as the number of transmit antennas grows large. As a result, there has also been strong interest in devising alternative approaches. One such approach is that of layered architectures, which incorporate multiple scalar encoders, one per transmit antenna. In these architectures, input data is demultiplexed into multiple substreams, which are then separately encoded and radiated from the various transmit antennas (Figure 1b). At the receiver, the substreams are successively detected and cancelled [4, 5]. Specifically, the information extracted from each substream is reencoded, interleaved, and modulated to construct a replica of the transmitted substream. This replica, properly combined with the channel response, is then subtracted from the overall received signal so that—if there are no errors—the interference contribution of this substream is removed. The complexity of these architectures increases more gracefully with the number of antennas. Furthermore, they can capitalize on existing scalar coding formats.

A layered architecture can approach the MIMO channel capacity if the data rates of the different transmit antennas are appropriately adjusted [23, 24]. This adjustment requires separate CQI, one per transmit antenna, and thus the amount of feedback required increases linearly with the number of transmit antennas. We hereby refer to it as per-antenna rate and CQI. Alternatively, a common CQI—and thus the same data rate—can be used for all transmit




(a) MIMO with joint coding.




(b) MIMO with per-antenna coding.

FIGURE 1: MIMO transmitter architecture with different coding structures.

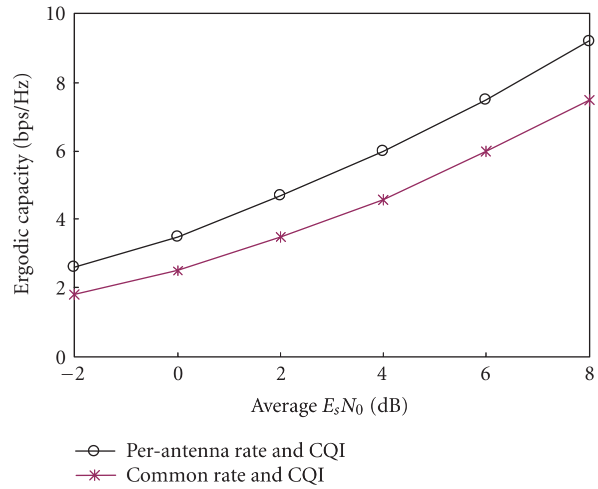



FIGURE 2: Ergodic Shannon capacity with 4 transmit and 4 receive antennas obtained via Monte Carlo simulation on a Rayleigh-faded channel with no antenna correlation.

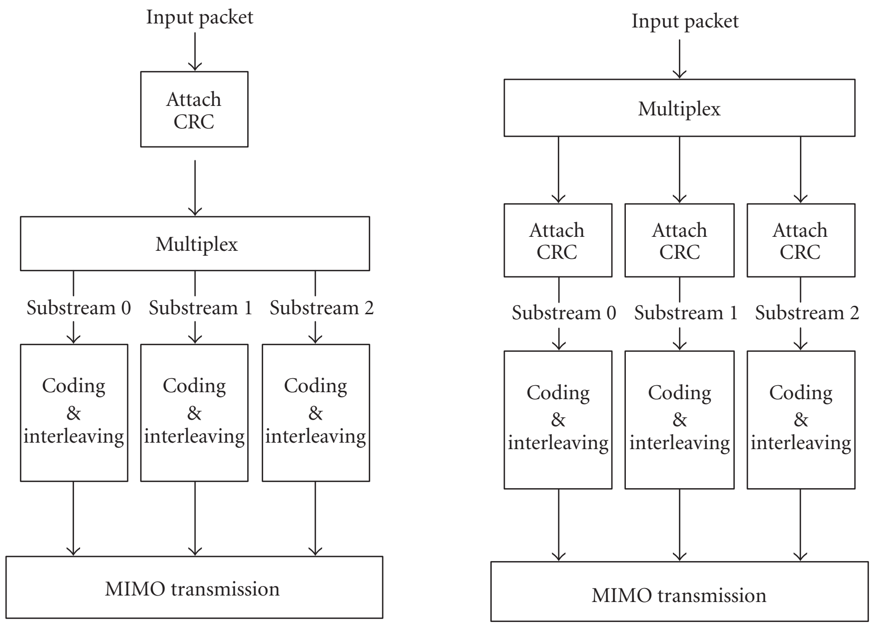
antennas at the expense of some loss in capacity [23]. To illustrate this point, Figure 2 depicts the difference between the capacity with and without the constraint that the data rate at each of the transmit antennas be equal, for the specific case of 4 transmit and 4 receive uncorrelated antennas with Rayleigh fading. For the purpose of this paper, in any event, the most relevant feature of a layered architecture is that it does not constraint the transmit antennas to be jointly encoded and share a unique CRC.

## 3. HARQ MECHANISMS FOR MIMO SYSTEMS

If the MAC layer is unaware of the presence of MIMO at the physical layer, HARQ simply attaches a single CRC to the packet with such CRC encompassing the data radiated from the various transmit antennas. We refer to this scheme, depicted in Figure 3a, as MIMO single ARQ (MSARQ). Since substreams transmitted from different antennas encounter distinct propagation channels, they have different error statistics. Using a typical channel propagation model with 4 transmit and 4 receive uncorrelated antennas [21], we observe that in more than 70% of error events,[2] only the substreams from 1 or 2 transmit antennas are corrupted and thus require a retransmission (Figure 4). However, upon an error event, an MSARQ receiver has to request a retransmission of the entire packet because it relies on the single CRC over the whole packet. Retransmitting substreams that have already been correctly received wastes throughput. When multiple per-antenna encoders are used, it becomes possible to remove the constraint that the substreams radiated from multiple transmit antennas share a single ARQ process.

For per-antenna MIMO encoding architectures, we herein propose to employ multiple ARQ processes, 1 for each substream radiated from 1 transmit antenna or group of antennas. This scheme is independent of the receiver-processing algorithm and only requires that the receiver decodes substreams independently. We refer to this scheme as MIMO multiple ARQ (MMARQ). As shown in Figure 3b, a CRC symbol is appended to each substream. At the receiver, each such substream is decoded and the associated CRC is used to validate the content. Multiple acknowledgment (NACK/ACK) indications are then sent back to the transmitter. After receiving these acknowledgements, the transmitter sends fresh packets from the transmit antennas that have been successfully acknowledged and retransmits the substreams that have been negatively acknowledged through their associated transmit antennas. Hence, the HARQ operations at different transmit antennas are independent of each other. We focus on high-speed downlink data transmission so that the overhead due to multiple CRC symbols is negligible. However, we need to consider the uplink signaling overhead due to multiple acknowledgements. For each ARQ process, NACK/ACK requires an overhead of 1 bit plus error protection redundancy. Therefore, the amount of ARQ feed-

[2]An error event occurs when any of the substreams contains an error.




(a) MSARQ transmitter.

(b) MMARQ transmitter.

Figure 3: Transmitter structures of MSARQ and MMARQ.

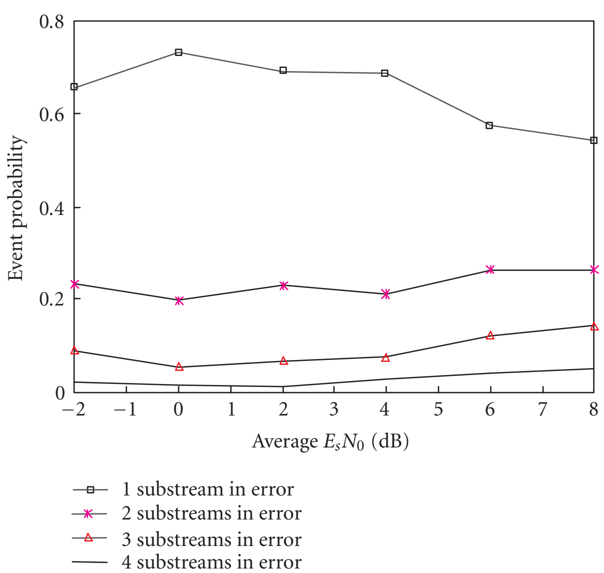



Figure 4: Probability distribution of the number of corrupted substreams in an error event with 4 transmit and 4 receive uncorrelated antennas and frequency-flat fading.

back overhead scales with the number of transmit antennas. When that number is large, grouping the transmit antennas and assigning a single ARQ process to each group can reduce the signaling overhead.

Next, using per-antenna encoders with successive decoding and cancellation at the receiver as an example, we describe the receiving procedures for both MMARQ and MSARQ. The receiver decodes the transmitted substreams sequentially following a certain order, which can be optimized to achieve the best throughput performance. The first substream is decoded from the overall aggregate received signal $\mathbf{Y}(t)$. The information data $S_0(t)$, extracted from substream 0, is then reencoded, interleaved, and modulated to construct a replica of the transmitted substream. This replica, combined with the channel response, that is, $F(S_0(t), \mathbf{H}(t))$, is then subtracted from $\mathbf{Y}(t)$ so that the interference contribution of this substream to the others is removed. This procedure is the so-called interference cancellation. The same process is then applied to the remaining substreams, which are thus successively extracted.

For MMARQ, the interference cancellation and HARQ packet combining procedures can be blended advantageously. In that case, the receiver would decode a substream and use its associated CRC to validate the content. If this substream carries a retransmission packet and contains uncorrectable errors, the soft symbols of the packet would be combined with those of the previous transmission(s) to extract the information data. The receiver would then perform interference cancellation to remove the interference due to this substream. Interference cancellation is performed regardless of the results of the CRC validation; therefore, all the subsequent substreams can be decoded without waiting for the retransmission of the current substream. However, the reliability of the decoded data is much higher after HARQ packet combining and, thus, using such data to reconstruct the signal replicas for interference cancellation reduces error propagation. The detailed receiver procedure is shown in Figure 5.

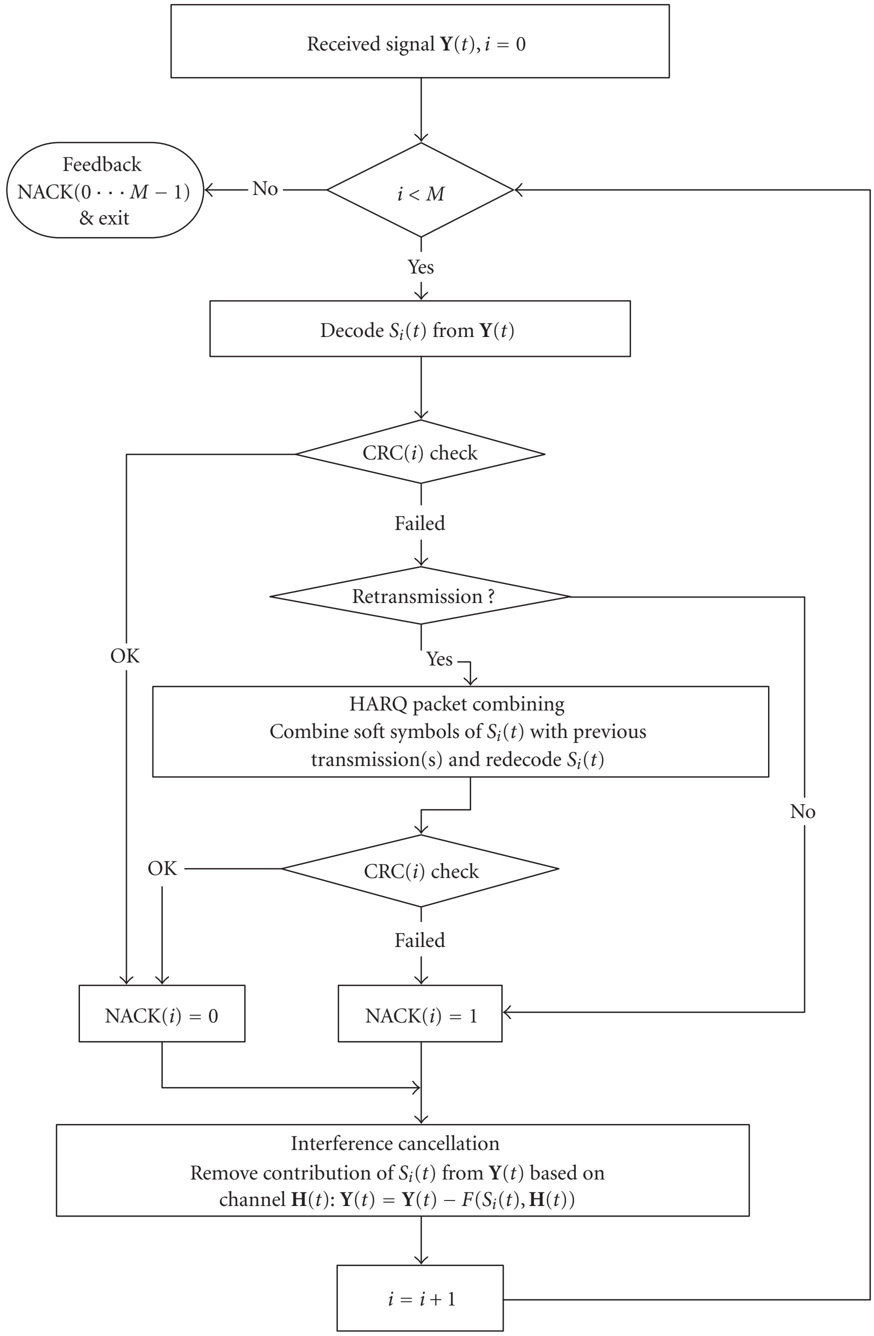



Figure 5: MMARQ receiver flow chart.

In contrast, it is not so easy to combine HARQ with interference cancellation when MSARQ is employed. As illustrated in Figure 6, MSARQ separates HARQ packet combining from interference cancellation. The receiver performs packet decoding and interference cancellation to extract the substreams and then combines those substreams into a compound packet. In this case, decoding errors at each substream could propagate to the substreams that are decoded afterwards. Such error propagation could severely degrade the performance. Another alternative would be to recancel interference on the HARQ combined signal upon a CRC failure. This procedure is shown in Figure 7, wherein interference cancellation is conducted twice. We refer to it as MSARQ IC. The resulting hardware design, however, could be problematic, as the receiver would need to quickly feedback the NACK indicator to the transmitter.

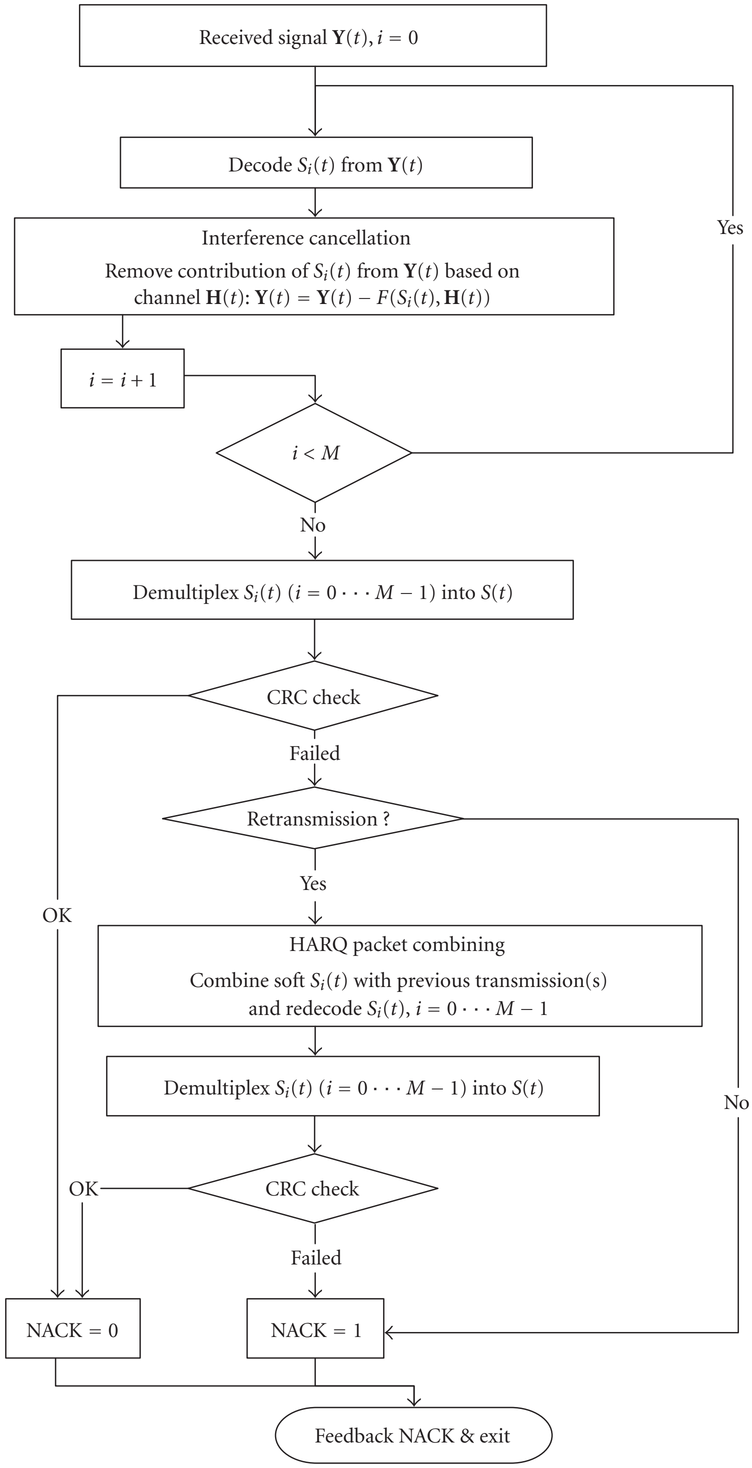



Figure 6: MSARQ receiver flow chart type I.

## 4. COMPARISON OF MSARQ AND MMARQ

In this section, we compare the performance of MSARQ and MMARQ in the context of UMTS HSDPA [25]. The most prominent features of HSDPA, which is specifically geared towards delay-tolerant data, are as follows.

(1) A fraction of the power and code space available at the base station is allocated to HSDPA while the rest is assigned to pilots, overhead channels, and voice traffic.

(2) HSDPA users are time-multiplexed in short frames. A scheduler at the MAC layer determines the user to be served at each frame. Each scheduling interval or

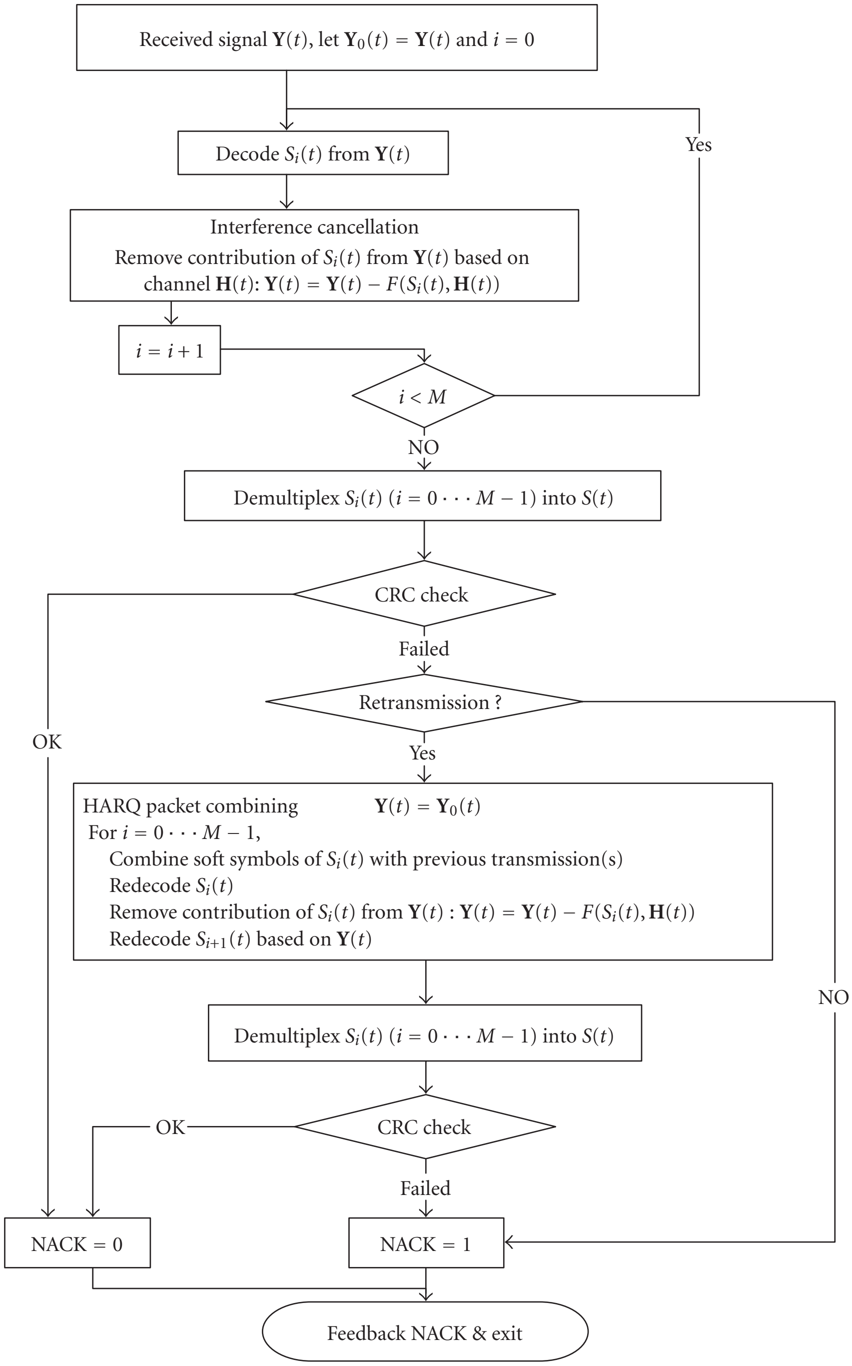



Figure 7: MSARQ IC receiver flow chart.

frame lasts 2 milliseconds. We assume that the entire HSDPA code space (10 codes in this paper) and transmit power are assigned to the scheduled user. That is, the base station transmits to only one user in each frame using 10 codes and full power. The transmit signal consists of a superposition of such 10 orthogonal codes.

(3) The Node B (or base station) MAC determines the transmission rate for the user being served, based on the CQI.

(4) The HARQ functionality resides between the Node B and the mobile terminal to permit soft combining and fast NACK/ACK feedback.

We have developed a simulation tool that captures the dynamic processes in a radio network. The simulated radio network consists of a base station (Node B) and multiple user terminals. The Node B possesses the following functionalities.

(a) $MAC_{HSDPA}$. It performs scheduling, MCS selection, and HARQ, based on the CQI feedback and the NACK/ACK signaling from each terminal.

(i) *Scheduler*. System performance depends heavily on the scheduling algorithm. For the purpose of this work, we limit ourselves to a round-robin scheduler, which exhibits maximum fairness across users. Additionally, with such scheduler, it is easy to quantify the system-level performance from the single-user performance.

(ii) *MCS selection*. The MCS at each transmit antenna is separately controlled through CQI feedback from the receiver [23, 24].

(iii) *HARQ*. The downlink HARQ operates asynchronously, that is, the retransmissions can take place anytime after the Node B receives a NACK/ACK. The scheduler determines the exact time. To compensate for the NACK/ACK feedback delay of 2 frames, each HARQ entity operates in terms of three stop-and-wait (SAW) processes. This allows HARQ to operate continuously without waiting for a NACK/ACK signal. For MSARQ, all transmit antennas use a single HARQ entity with 3 processes while, for MMARQ, each transmit antenna uses one HARQ entity with 3 processes. Chase combining is used to combine the initial transmission with the retransmissions. The maximum number of retransmissions is 30. If a corrupted packet cannot be recovered after exhausting the maximum number of retransmissions, the packet is discarded and the associated loss should be recovered by higher layer error control mechanism.

(b) *PHY*. The physical layer simulation consists of a sequence of events such as transmission and reception of signals, signal-to-interference-and-noise ratio (SINR) evaluation, and channel estimation. It employs a bandwidth of 5 MHz with 3.33-milliseconds frames. We assume that the uplink channel operates at a rate of 64 kbps. At the terminal, the substreams radiated by the various transmit antennas are decoded according to a fixed order. The MCS of each such substream is selected based on its detected SINR at the receiver and it is then fed back as a CQI message. Some additional premises are summarized below:

(i) fading is Rayleigh-distributed and frequency-flat and the channel is either perfectly known at the receiver or modeled by adding simulated estimation noise onto the actual channel;
(ii) pedestrian speed (3 Km/hr);
(iii) 70% of transmit power dedicated to HSDPA;
(iv) 10 out of 16 orthogonal codes dedicated to HSDPA;
(v) 4 uncorrelated transmit and 4 uncorrelated receive antennas;
(vi) 7 MCSs employing turbo codes with varying rates and symbol repetition [4]: QPSK rate 1/4 repeated 4 times, QPSK rate 1/4 repeated 2 times, QPSK rate 1/4, QPSK rate 1/2, QPSK rate 3/4, 16-QAM rate 1/2, and 16-QAM rate 3/4.

The probability of each substream being detected erroneously is given by a frame error rate (FER) versus instantaneous SINR curve for each MCS. For the above MCS schemes, these curves are displayed in Figure 8.

The ultimate performance measure is the single-user throughput, defined as the ratio between the number of information bits correctly received by a user and the time that the channel is allocated to that user:

$$\text{throughput} = \frac{\text{total good bits}}{(\text{total frames with transmissions}) \cdot \text{frame duration}}. \tag{1}$$

Notice that the throughput represents the peak net throughput that can be delivered to a user.

It should be pointed out that the throughput depends on the mapping between the detected SINR and the selected MCS per antenna. Such mapping is adjusted in order to maximize the throughput while maintaining some target FER measured prior to HARQ operation. When this target FER is small (less than 5%), the probability of retransmission is low and there is no large gain with any kind of ARQ. As the target FER increases, the probability of retransmissions grows and there is a considerable gain with MMARQ. Hence, we optimize the FER to maximize the throughput.

### 4.1. Performance with perfect channel estimation and feedback

Our initial simulations assume perfect channel estimation and error-free uplink feedback. We first examine the advantage of combining HARQ with interference cancellation by comparing the compound packet error performance of MSARQ and MSARQ IC. Separating interference cancellation from HARQ combining fails to eliminate the interference from any corrupted substream even if the substream is later fully recovered through HARQ packet combining. Such inefficiency results in a higher compound packet error rate (Figure 9). To quantify the advantage of per-antenna HARQ in MMARQ, the throughput performances of MMARQ, MSARQ, and MSARQ IC are compared in Figure 10. We observe that MMARQ achieves 10%–20% improvement over MSARQ IC and 26%–40% over MSARQ. Thus, the contributions of combined operation and multiple ARQ structures are roughly equal. The ergodic Shannon capacities for open-loop single-transmit single-receive and 4-transmit 4-receive configurations are also shown in the same figure as references.

In the above example, MSARQ, MSARQ IC, and MMARQ use the same MCS/SINR settings, which maximize the throughput for MMARQ but not necessarily for MSARQ and MSARQ IC. Through additional simulations, we find that the optimal MCS/SINR settings for MSARQ and MSARQ IC yield a compound FER of 8%–10%, while the optimal FER for MMARQ is around 15%–20%. The

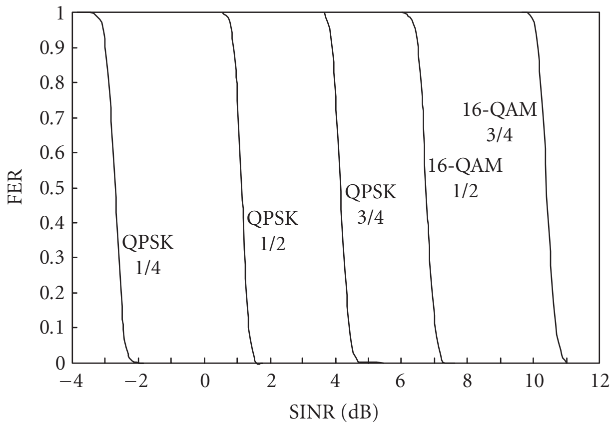



Figure 8: Frame error rate (FER) versus SINR for a single transmit and a single receive antenna.

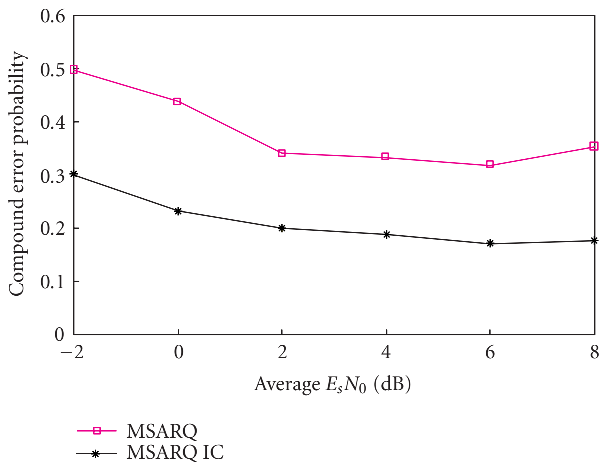



Figure 9: Compound packet error rate of MSARQ and MSARQ IC.

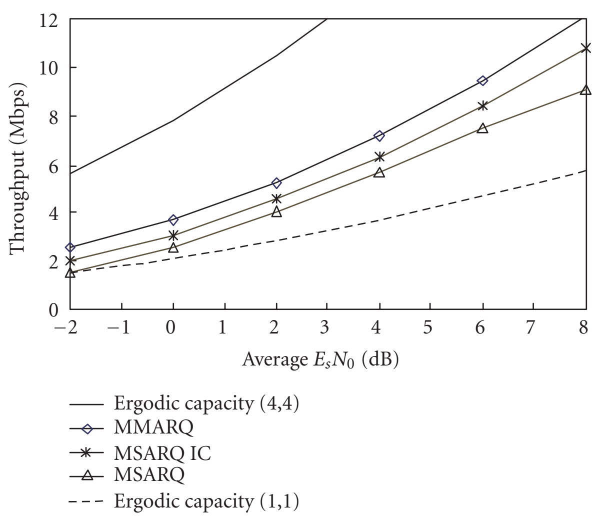



Figure 10: Throughputs of MMARQ, MSARQ, and MSARQ IC with interference cancellation in ideal conditions.

corresponding individual substream error rates are 2%–5% and 8%–18%, respectively. In practice, it is quite difficult to guarantee a substream error rate of 5% or less. Therefore, the optimal throughput of MMARQ would be easier to achieve in a realistic environment. Nevertheless, the optimized throughputs are shown in Figure 11, where the improvement of MMARQ drops to around 10% with respect to MSARQ IC and 20% with respect to MSARQ. By operating at a low packet error rate, channel coding and packet combining can eliminate most channel errors. As such, the throughput gap between MSARQ and MSARQ IC also diminishes.

### 4.2. *Performance with imperfect channel estimation and feedback*

Next, we examine the performance of MSARQ, MSARQ IC, and MMARQ in more realistic conditions, with imperfect channel estimation and imperfect uplink feedback. The main sources of imperfection are limited pilot power, finite channel coherence time, and feedback delay. We model these nonidealities by adding noise to the SINR, that is,

$$\hat{\gamma}_{\mathrm{dB}} = \gamma_{\mathrm{dB}} + N(0, \sigma_a^2), \qquad (2)$$

where $\hat{\gamma}_{\mathrm{dB}}$ represents the SINR in dB as estimated by the receiver, $\gamma_{\mathrm{dB}}$ represents the actual SINR in dB, and $N(0, \sigma_a^2)$ represents Gaussian noise with variance $\sigma_a^2$. The estimation error not only impacts the MIMO signal detection and decoding process, but also impacts the MCS selected for each transmit antenna. In addition, the uplink feedback channel also encounters a uniformly distributed binary error rate of 6%, which could corrupt the CQI and the NACK/ACK indication(s). Figure 12 illustrates the throughput performance of MMARQ, MSARQ, and MSARQ IC for $\sigma_a^2 = 1.5$ dB. The performance degradations range from 10% to 18% for MMARQ, 17% to 32% for MSARQ, and 16% to 24% for MSARQ IC. Relatively, MMARQ is less sensitive to channel estimation noise and feedback errors. As the level of uncertainty increases, it becomes more difficult to guarantee a successful transmission without sacrificing packet throughput. In this case, it is beneficial to transmit aggressively and use HARQ to recover from channel errors. Overall, MMARQ achieves 30%–45% throughput improvement over MSARQ, while per-antenna ARQ contributes to a 15%–25% throughput improvement.

## 5. CONCLUSION

We have proposed a new ARQ scheme suitable for any MIMO scheme in which substreams radiated from different antennas are encoded separately. Conventionally, a single ARQ process is applied to each data packet. Upon an error event, all constituent substreams—including those that have already been correctly received—are retransmitted. In contrast, our proposed scheme separates the ARQ processes for the substreams. We have quantified the gains of the new scheme within the context of UMTS high-speed downlink data access. We first considered ideal conditions with perfect

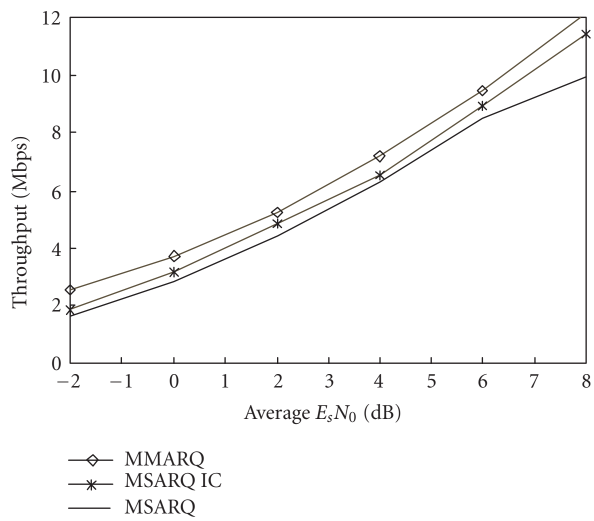



Figure 11: Throughputs of MMARQ, MSARQ, and MSARQ IC with interference cancellation in ideal conditions using the optimized MCS/SINR settings.

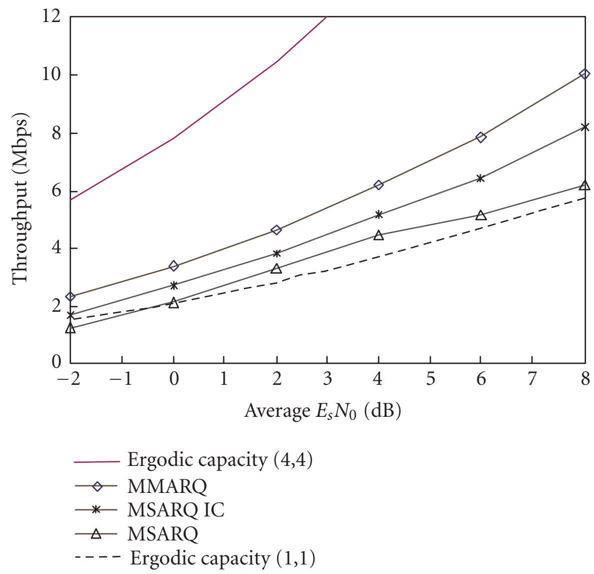



Figure 12: Throughput of MMARQ, MSARQ, and MSARQ IC with interference cancellation in realistic conditions (with imperfect channel estimation and imperfect uplink feedback).

channel estimation and error-free uplink feedback, where MMARQ improves the throughput by 25%–40%. We then performed the simulations in more realistic conditions, with imperfect channel estimation and possibly erroneous uplink feedback. Such uncertainty leads to a higher loss rate, and HARQ becomes a major technique for efficient error control and recovery. Hence, MMARQ is even more favorable with the performance improvement increasing to 30%–45% compared with MSARQ. It should be pointed out that the results presented here are based on the premise of frequency-flat fading and uncorrelated antennas. Frequency-selective fading may modify this conclusion, and this problem is currently under investigation.

Traditionally, the physical layer had been considered the performance bottleneck in wireless systems due to the unpredictable nature of the radio channel. Higher layer issues, such as scheduling, link adaptation, retransmissions, and mobile routing, used to be discussed and treated separately from major physical layer issues. With the convergence of mobile communications and data services, however, there is a growing need for a cross-layer design that facilitates the interaction of multiple protocol layers. In particular, one can couple the design of link layer (i.e., MAC and RLP) with that of the physical layer. The superior performance of MMARQ confirms the benefits of such joint layer design.

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**Haitao Zheng** received her B.S. degree with highest honor in electrical engineering from Xian Jiaotong University, China, in 1995, the M.S. and Ph.D. degrees in electrical engineering from the University of Maryland, College Park, MD, in 1998 and 1999, respectively. From 1995 to 1998, she was an Institute for System Research Fellow at University of Maryland. She received the 1998-1999 George Harhalakis Outstanding Systems Engineering Graduate Student Award in recognition of outstanding contributions in cross-disciplinary research from the University of Maryland. Since August 1999, she is with Wireless Research Laboratory, Bell Labs, Lucent Technologies, Holmdel, NJ. Her research interests include wireless communications and networking, multimedia communications, and signal processing. Recently, she received the Bell Laboratories 2002 Presidents Gold Award in recognition of outstanding level of innovation, technical excellence, and business impact. She currently serves as the TPC Member of IEEE Multimedia Signal Processing Technical Committee, TPC of ICME 2003, TPC of Globecom 2003, Guest Editor of the IEEE JSAC Special Issue on Advanced Mobility Management and QoS Protocols for Wireless Internet, and Guest Editor of the EURASIP Journal on Applied Signal Processing Special Issue on Cross Layer Design for Communications and Signal Processing. She has served as the TPC Member of ICME 2002, ICC 2003, ICASSP 2002, and so forth.

**Angel Lozano** was born in Manresa, Spain, in 1968. He received his Engineer degree in telecommunications (with honors) from the Polytechnical University of Catalonia, Barcelona, Spain, in 1992 and his M.S. and Ph.D. degrees in electrical engineering from Stanford University, Stanford, Calif, in 1994 and 1998, respectively. Between 1996 and 1998, he worked for Pacific Communication Sciences Inc. and for Conexant Systems in San Diego, Calif. Since January 1999, he has been with Bell Laboratories, Lucent Technologies, Holmdel, NJ. Since October 1999, Dr. Lozano has served as Associate Editor for IEEE Transactions on Communications. He holds 6 patents.

**Mohamed Haleem** received his B.S. Eng. degree from the Department of Electrical and Electronic Engineering, University of Peradeniya, Sri Lanka in 1990, the M.Phil. degree from the Department of Electrical & Electronic Engineering, Hong Kong University of Science & Technology, in 1995, and is currently working toward his Ph.D. degree in electrical engineering at Stevens Institute of Technology, Hoboken, NJ. He was with the academic staff of the Department of Electrical & Electronic Engineering, University of Peradeniya, from 1990 to 1993, and has been with the Wireless Communications Research Department, Bell Laboratories, Lucent Technologies at Crawford Hill, Holmdel, NJ, from 1996 to 2002. His research interests include dynamic resource assignment, channel adaptive transmission techniques for wireless communication systems, multiple antenna communication systems, and application of stochastic dynamic programming and optimization techniques to wireless communication systems.

EURASIP Journal on Image and Video Processing

# Special Issue on Distributed Video Coding

## Call for Papers

Distributed source coding (DSC) is a new paradigm based on two information theory theorems: Slepian-Wolf and Wyner-Ziv. Basically, the Slepian-Wolf theorem states that, in the lossless case, the optimal rate achieved when performing joint encoding and decoding of two or more correlated sources can theoretically be reached by doing separate encoding and joint decoding. The Wyner-Ziv theorem extends this result to lossy coding. Based on this paradigm, a new video coding model is defined, referred to as distributed video coding (DVC), which relies on a new statistical framework, instead of the deterministic approach of conventional coding techniques such as MPEG standards.

DVC offers a number of potential advantages. It first allows for a flexible partitioning of the complexity between the encoder and decoder. Furthermore, due to its intrinsic joint source-channel coding framework, DVC is robust to channel errors. Because it does no longer rely on a prediction loop, DVC provides codec independent scalability. Finally, DVC is well suited for multiview coding by exploiting correlation between views without requiring communications between the cameras.

High-quality original papers are solicited for this special issue. Topics of interest include (but are not limited to):

- Architecture of DVC codec
- Coding efficiency improvement
- Side information generation
- Channel statistical modeling and channel coding
- Joint source-channel coding
- DVC for error resilience
- DVC-based scalable coding
- Multiview DVC
- Complexity analysis and reduction
- DSC principles applied to other applications such as encryption, authentication, biometrics, device forensics, query, and retrieval

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| Manuscript Due | May 1, 2008 |
| First Round of Reviews | August 1, 2008 |
| Publication Date | November 1, 2008 |

### Guest Editors

**Frederic Dufaux,** Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland; frederic.dufaux@epfl.ch

**Wen Gao,** School of Electronic Engineering and Computer Science, Peking University, Beijing, China; wgao@pku.edu.cn

**Stefano Tubaro,** Dipartimento di Elettronica e Informazione, Politecnico di Milano, Milano, Italy; stefano.tubaro@polimi.it

**Anthony Vetro,** Mitsubishi Electric Research Laboratories, Cambridge, MA, USA; avetro@merl.com

EURASIP Journal on Bioinformatics and Systems Biology

# Special Issue on
# Network Structure and Biological Function: Reconstruction, Modelling, and Statistical Approaches

## Call for Papers

We are particularly interested in contributions, which elucidate the relationship between structure or dynamics of biological networks and biological function. This relationship may be observed on different scales, for example, on a global scale, or on the level of subnetworks or motifs.

Several levels exist on which to relate biological function to network structure. Given molecular biological interactions, networks may be analysed with respect to their structural and dynamical patterns, which are associated with phenotypes of interest. On the other hand, experimental profiles (e.g., time series, disturbations) can be used to reverse engineer network structures based on a model of the underlying functional network.

Is it possible to detect the interesting features with the current methods? And how is our picture of the relationsship between network structure and biological function affected by the choice of methods?

Perspectives both from simulation approaches as well as the evaluation of experimental data and combinations thereof are welcome and will be integrated within this special issue.

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| Manuscript Due | June 1, 2008 |
| First Round of Reviews | September 1, 2008 |
| Publication Date | December 1, 2008 |

### Guest Editors

**J. Selbig,** Bioinformatics Chair, Institute for Biochemistry and Biology, University of Potsdam, Germany; selbig@mpimp-golm.mpg.de

**M. Steinfath,** Institute for Biochemistry and Biology, University of Potsdam, Germany; steinfath@mpimp-golm.mpg.de

**D. Repsilber,** AG Biomathematics & Bioinformatics, Genetics and Biometry and Genetics Section, Research Institute for the Biology of Farm Animals, Dummerstorf, Germany; repsilber@fbn-dummerstorf.de

# Special Issue on
# Design and Architectures for Signal and Image Processing

## Call for Papers

The development of complex applications involving signal, image, and control processing is classically divided into three consecutive steps: a theoretical study of the algorithms, a study of the target architecture, and finally the implementation.

Today such sequential design flow is reaching its limits due to:

- The complexity of today's systems designed with the emerging submicron technologies for integrated circuit manufacturing
- The intense pressure on the design cycle time in order to reach shorter time-to-market, reduce development and production costs
- The strict performance constraints that have to be reached in the end, typically low and/or guaranteed application execution time, integrated circuit area, overall system power dissipation

An alternative approach to a traditional design flow, called algorithm-architecture matching, aims to leverage the design flow by a simultaneous study of both algorithmic and architectural issues, taking into account multiple design constraints, as well as algorithm and architecture optimizations, not only in the beginning but all the way throughout the design process.

Introducing such design methodology is also necessary when facing the new emerging applications such as high-performance, low-power, low-cost mobile communication systems and/or smart sensors-based systems.

This design methodology will have to face also future architectures based on multiple processor cores and dedicated coprocessors to achieve the required efficiency. NoC-based communications will become also mandatory for many applications to enable parallel interconnections and communication throughputs. Adaptive and reconfigurable architectures represent a new computation paradigm whose trend is clearly increasing.

This forms a driving force for the future evolution of embedded system designs methodologies.

This special issue of the EURASIP Journal of Embedded Systems is intended to present innovative methods, tools, design methodologies, and frameworks for algorithm-architecture matching approach in the design flow including system level design and hardware/software codesign, RTOS, system modeling and rapid prototyping, system synthesis, design verification and performance analysis and estimation. Because in such design methodology the system is seen as a whole, this special issue will also cover the following topics:

- New and emerging architectures: SoC, MPSoC, configurable computing (ASIPs), (dynamically) reconfigurable systems using FPGAs
- Smart sensors: audio and image sensors for high performance and energy efficiency
- Applications: Automotive, medical, multimedia, telecommunications, ambient intelligence, object recognition, cryptography, wearable computing

This special issue is open to all contributions. Authors are invited to submit their papers addressing the domain of design and architectures for signal and image processing. We also strongly encourage authors who presented a paper to the DASIP 2007 workshop to submit an extended version of their original workshop contributions.

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| Manuscript Due | March 1, 2008 |
| First Round of Reviews | June 1, 2008 |
| Publication Date | September 1, 2008 |

**EURASIP Journal on Embedded Systems**

**Guest Editors**

**Markus Rupp,** Institute of Communications and Radio-Frequency Engineering (INTHFT), Technical University of Vienna, 1040 Vienna, Austria; mrupp@nt.tuwien.ac.at

**Dragomir Milojevic,** BEAMS, Université Libre de Bruxelles, CP165/56, 1050 Bruxelles, Belgium; dragomir.milojevic@ulb.ac.be

**Guy Gogniat,** LESTER Laboratory, University of South Brittany, FRE 2734 CNRS, 56100 Lorient, France; guy.gogniat@univ-ubs.fr

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EURASIP Journal on Wireless Communications and Networking

# Special Issue on Fairness in Radio Resource Management for Wireless Networks

## Call for Papers

Radio resource management (RRM) techniques (such as admission control, scheduling, sub-carrier allocation, channel assignment, power allocation, and rate control) are essential for maximizing the resource utilization and providing quality of service (QoS) in wireless networks.

In many cases, the performance metrics (e.g., overall throughput) can be optimized if opportunistic algorithms are employed. However, opportunistic RRM techniques always favor advantaged users who have good channel conditions and/or low interference levels. The problem becomes even worse when the wireless terminals have low mobility since the channel conditions become slowly varying (or even static), which might lead to long-term unfairness. The problem of fair resource allocation is more challenging in multihop wireless networks (e.g., mesh and multihop cellular networks).

The performance fairness can be introduced as one of the QoS requirements (e.g., as a condition on the minimum throughput per user). Fair RRM schemes might penalize advantaged users; hence, there should be a tradeoff between the overall system performance and the fairness requirements.

We are soliciting high-quality unpublished research papers addressing the problem of fairness of RRM techniques in wireless communication systems. Topics include (but are not limited to):

- Fairness of scheduling schemes in wireless networks
- Tradeoff between maximizing the overall throughput and achieving throughput fairness
- RRM fairness: problem definition and solution techniques
- Fairness performance in emerging wireless systems (WiMAX, ad hoc networks, mesh networks, etc.)
- Cross-layer RRM design with fairness
- Short-term and long-term fairness requirements
- Adaptive RRM to support fairness
- Fairness in cooperative wireless communications
- Issues and approaches for achieving fairness in multihop wireless networks
- RRM framework and QoS architecture
- Complexity and scalability issues
- Experimental and implementation results and issues
- Fairness in multiple-antenna transmission/reception systems
- Fairness in end-to-end QoS provisioning

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| Manuscript Due | July 1, 2008 |
| First Round of Reviews | October 1, 2008 |
| Publication Date | January 1, 2009 |

### Guest Editors

**Mohamed Hossam Ahmed,** Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NF, Canada A1B 3V6; mhahmed@engr.mun.ca

**Alagan Anpalagan,** Department of Electrical and Computer Engineering, Ryerson University, Toronto, ON, Canada M5G 2C5; alagan@ee.ryerson.ca

**Kwang-Cheng Chen,** Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan; chenkc@cc.ee.ntu.edu.tw

**Zhu Han,** Department of Electrical and Computer Engineering, College of Engineering, Boise State University Boise, Idaho, USA; zhuhan@boisestate.edu

**Ekram Hossain,** Department of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB, Canada R3T 2N2; ekram@ee.umanitoba.ca

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EURASIP Journal on Image and Video Processing

# Special Issue on 3D Image and Video Processing

## Call for Papers

3D image and 3D video processing techniques have received increasing interest in the last years due to the availability of high-end capturing, processing, and rendering devices. Costs for digital cameras have dropped significantly and they allow the capturing of high-resolution images and videos, and thus even multi-view acquisition becomes interesting in commercial applications. At the same time, processing power and storage have reached the level that allows the real-time processing and analysis of 3D image information. The synthesized 3D information can be interactively visualized on high-end graphics boards that become available even on small mobile devices. 3D displays can additionally help to increase the immersiveness of a 3D framework. All these developments move the interest in 3D image and video processing methods from a more academic point of view to commercially attractive systems and enable many new applications such as 3DTV, augmented reality, intelligent human-machine interfaces, interactive 3D video environments, and much more.

Although the technical requirements are more and more fulfilled for a commercial success, there is still a need of sophisticated algorithms to handle 3D image information. The amount of data is extremely high, requiring efficient techniques for coding, transmission, and processing. Similarly, the estimation of 3D geometry and other meta data from multiple views, the augmentation of real and synthetic scene content, and the estimation of 3D object or face/body motion have been addressed mainly for restricted scenarios but often lack robustness in a general environment. This leaves many interesting research areas in order to enhance and optimize 3D imaging and to enable fully new applications. Therefore, this special issue targets at bringing together leading experts in the field of 3D image and video processing to discuss and investigate this interesting topic.

Specifically, this special issue will gather high-quality, original contributions on all aspects of the analysis, interaction, streaming, and synthesis of 3D image and video data. Topics of interest include (but are not limited to):

- 3D image and video analysis and synthesis
- Face analysis and animation
- 3D reconstruction
- Object recognition and tracking
- 3D video/communications
- Streaming of 3D data
- Augmented/mixed reality
- Image-based rendering
- Free viewpoint video

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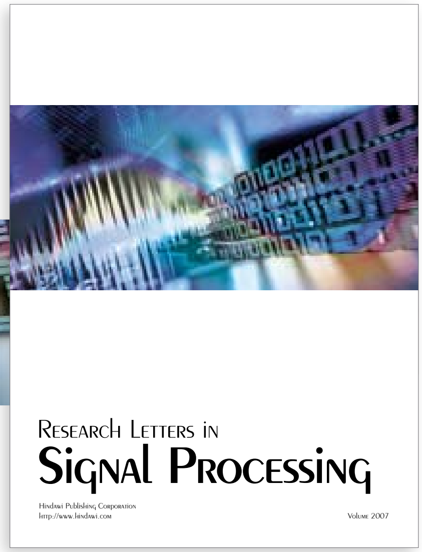
| Manuscript Due | March 1, 2008 |
| First Round of Reviews | June 1, 2008 |
| Publication Date | September 1, 2008 |

### Guest Editors

**Peter Eisert,** Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Berlin, Germany; eisert@hhi.fraunhofer.de

**Marc Pollefeys,** Department of Computer Science, University of North Carolina at Chapel Hill, USA, Institute for Computational Science, ETH Zurich, Switzerland; marc@cs.unc.edu

**Stefano Tubaro,** Dipartimento di Elettronica e Informazione, Politecnico di Milano, Milano, Italy; stefano.tubaro@polimi.it







ISSN: 1687-6911; e-ISSN: 1687-692X; doi:10.1155/RLSP

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