Application

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Descriptive data

Project info

Project title (Swedish)*

Wireless Network Calculus

Project title (English)*

Wireless Network Calculus

Abstract (English)*

Future wireless networks will be facing much tougher requirements regarding latency and reliability. These requirements are motivated by application scenarios like industrial automation and car-to-car communications, to just name a few. Todays' networks are not capable of meeting these requirements, as they mainly have been designed for Internet applications as well as communication between humans. However, from a theoretical point of view, we lack the understanding how to build these systems, in particular taking the entire network stack into account which then implies the consideration of queuing effects. Recently, there has been a major breakthrough in the analytical evaluation of wireless network queuing performance. This new approach allows a much more precise description, in particular of the delay violation probability of a series of queues served by wireless links.

Hence, this project will leverage these recent results to lay analytical foundations of wireless networks with low latency and security constraints. In particular, we stress the interest of the project to derive limits with respect to latency and reliability which - from a theoretical point of view - cannot be met. With respect to low latency, recent information-theoretic results are now known that describe the achievable rate of a single link much more accurate than before. These insights will be combined in this project with the novel queuing approach, and subsequently several system optimizations will be studied afterwards. With respect to security, we will address information-theoretic secure communication as well as physical layer authentication schemes, and develop queuing-theoretic models for both of these schemes. Finally, new so called integrated communication/processing paths will be studied which are the foundation for upcoming applications like control. In total, the project will thus lay foundations for the design of future wireless systems, and in particular by providing hard limits of achievable network performance.

Popular scientific description (Swedish)*

Framtida trådlösa nätverk kommer att möta allt tuffare krav avseende fördröjning och tillförlitlighet. Dessa krav motiveras av tillämpningsscenarier såsom industriell automation och bil-till-bil kommunikation, för att bara nämna några. Dagens nätverk är inte kapabla att möta dessa krav eftersom de huvudsakligen har blivit designade för Internettillämpningar samt för kommunikation mellan människor. Dock, från en teoretisk synvinkel, så saknar vi en god förståelse för hur vi ska bygga dessa system, särskilt då hänsyn tas till alla nätverkslager vilket då innebär att köeffekter beaktas. Nyligen har det dock skett ett betydande genombrott för att analytiskt kunna karaktärisera köprestanda för trådlösa nät. Denna nya metodik tillåter en mycket mer precis beskrivning, särskilt med avseende på sannolikheten för att en viss fördröjning överskrids när en serie av köer med mellanliggande trådlösa länkar beaktas.

Således avser detta projekt att dra nytta av dessa nya resultat för att anlägga en analytisk grund till att förstå trådlösa nätverk med låg fördröjning och säkerhetsvillkor. Särskilt vill vi betona projektets målsättning med att härleda gränsvärden för fördröjning och tillförlitlighet som – från en teoretisk synvinkel – inte kan mötas. Beträffande låga fördröjningar så är nya informationsteoretiska resultat nu kända vilka beskriver den möjligt uppnåbara datahastigheten för en enskild länk mycket mer precist än tidigare. Dessa insikter kommer i projektet att kombineras med nya kötekniker, och därefter kommer många olika optimeringar av systemet att studeras. Beträffande säkerhet, så kommer vi att beakta informationsteoretisk säker kommunikation såväl som autentiseringsmetoder på det fysiska lagret, och då utveckla köteoretiska modeller för båda dessa metoder. Slutligen så kommer så kallade integrerad kommunikation/processeringsvägar att studeras vilka utgör grunden för kommande tillämpningar såsom kontroll. För att summera, projektet lägger således grunden för design av framtida trådlösa nätverk, och då mer precist genom att ge exakta gränsvärden för maximalt uppnåbar nätverksprestanda.

Project period

Number of project years*

4

Calculated project time*

2016-01-01 - 2019-12-31

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*

2. Teknik > 202. Elektroteknik och elektronik > 20204. Telekommunikation

2. Teknik > 202. Elektroteknik och elektronik > 20203. Kommunikationssystem

1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10202. Systemvetenskap, informationssystem och informatik (samhällsvetenskaplig inriktning under 50804)

Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

Network Calculus

Keyword 2*

Wireless Communications

Keyword 3*

Safety-critical applications

Keyword 4

Security

Keyword 5

Queuing theory

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

The proposal does not contain any ethical issues.

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

1 Purpose and Aims

Performance evaluation of wireless networks is often limited to simulation and experimentation, as rigor analytical approaches from the queuing-theoretic domain can not capture the essentials of the physical layer. This limits fundamentally the insight on how to design wireless networks from a systems-perspective (i.e. from a link layer or even networking layer point of view, still taking into account the entire network stack). Furthermore, next generation wireless networks are expected to fulfill demanding requirements regarding latency, reliability and security, as the community is envisioning safety-critical low-latency automation or even human tactile communication as important applications. This leads to the unsatisfying situation that we have interesting applications with ambitious demands on the one hand, while on the other hand we do not have sufficient theoretical models and insights that can guide the design process *from a systems' point of view.* The goal of this project is to overcome this challenge. We will leverage own recent theoretical breakthroughs in the performance analysis of wireless networks in combination with recent information-theoretic models for blocklength-limited communication to establish theoretical foundations with respect to low-latency wireless system design. In addition, we will address security-related aspects as well as integrated communication-processing chains, arising for example in the context of critical control applications. Our insights will be disseminated by publishing in high-quality (IEEE) conferences and journals primarily, while graduate students will carry the methodology and research outcome into academic and industrial research at a later stage. We stress here the strategic value of fundamental understanding of wireless communication and network performance with respect to the novel upcoming safety-critical applications for the Swedish industry in general, and in particular for the Stockholm area with companies like Ericsson, Scania and ABB located close by.

2 Survey of the Field

Performance analysis and optimization of wireless networks have been addressed mainly using queuing-theoretic approaches. Traditionally, these approaches have either exploited established analytical results for M/M/1 systems (and networks thereof) or for M/G/1 systems. The main drawback of these traditional approaches is their limitations when it comes to the distributions of network performance metrics: Only average measures can be considered and most obtained results are case specific, which limits the insight obtained in general. The need for more tractable, as well as insightful analysis approaches for more realistic wireless setups triggered the development of the following three approaches over the last decade:

Effective Capacity Approach: In 2003 Wu and Negi [1] proposed an alternative queuing-analytic approach called the *effective capacity* of a wireless system. It is a more powerful performance model of a wireless system as it allows to approximate the tail distribution of the steady-state queue length and delay. Denoting by $S(0,i)$ the random cumulative service process of a wireless system during interval $[0,i]$, the effective capacity approach states that the tail distribution of the steady-state queue-length Q can be upper bounded by an exponential function, i.e. $\sup_t \Pr\{Q(t) > x\} \sim e^{-\theta^* \cdot x}, x \to \infty$ where $\theta^* > 0$ is the so-called quality-of-service exponent, which can be freely chosen under the condition that $r + \alpha(-\theta^*) = 0$ (where r is the constant arrival rate to the system). The function $\alpha(-\theta^*)$ is termed the effective capacity and is basically given by the log-moment generating function of $S(0,t)$ (normalized to θ^*). The strength of the effective capacity analysis of wireless systems is its potential to model all essential parameters of the physical layer directly (transmit power, bandwidth, fading, shadowing etc.). Nevertheless, the log-moment generating function of the resulting (analytically described) service process needs to be determined. This has turned out to be quite difficult for rigor, standard models of wireless transmission, i.e. exponential block-fading channel states with a Shannon-like mapping of the signal-to-noise ratio (SNR) to instantaneous service capacity [1]. Still, the effective capacity has been extensively used over the last decade to analyze various wireless systems [2, 3, 4] [JG8,JG37,JG46][1]. Apart from its mathematical challenges [5], the effective capacity is limited as it essentially only allows for single-hop analysis (in [6] the authors present an approach for two hops, which is very involved).

MGF-based Stochastic Network Calculus: In the early 90'sCruz [7] introduced a system-theoretic interpretation of (deterministic) queuing systems based on min,+ dioid algebra, which had fundamental impact on the field of performance analysis of networked systems. This original theory for deterministic systems was later on termed *network calculus* and about ten years ago extended to stochastic systems [8, 9]. In stochastic network calculus a queuing network (i.e. a series of concatenated servers) with stochastic arrival and departure processes is considered with the bivariate functions $A(\tau,t)$, $D(\tau,t)$ and $S_n(\tau,t)$ denoting the *cumulative* arrival, departure and service (of server n) of the network. Following this approach, we are usually interested in a bound on the tail of the stochastic delay $W(t)$ of a queuing system at time t, i.e. more precisely in the probability $\Pr[W(t) > w^\varepsilon] \leq \varepsilon$, where ϵ is also known as the *violation probability* for a target delay w^ε. Similar expressions can be found for the backlog. These bounds can be obtained in terms of the moment generating function (MGF) of the cumulative arrival and service processes for any θ [8]:

$$\mathsf{M}_{A(\tau,t)}(\theta) = \mathrm{E}\left[e^{\theta A(\tau,t)}\right] , \mathsf{M}_{S(\tau,t)}(\theta) = \mathrm{E}\left[e^{\theta S(\tau,t)}\right] ,$$

However, determining the MGF of the cumulative service process of wireless systems has been found to be a notoriously difficult problem. There are many papers dealing with all kinds of aspects of wireless systems in a stochastic network calculus context [10, 11, 12, 13]. Nevertheless, all this work abstracts the lower layer behavior of wireless systems into Markov chains, which is insufficient from a communication theoretic point of view.

Melllin-transform based Stochastic Network Calculus: Recently, a much more promising approach for wireless network analysis has been proposed in [14], where the queuing behavior is analyzed directly in the domain of channel variations. This can be interpreted as the *SNR domain* - thinking of bits as *SNR demands* that reside

[1]References starting with JG refer to the applicants' publication list provided separately from this application text.

in the system queue until these demands can be met by the channel; in contrast to the *bit domain* addressed by the MGF-based analysis above. Following this approach, the cumulative arrival, service and departure processes in the bit domain, i.e., A, D and S, are related to their SNR domain counterparts (represented in the following by calligraphic upper case letters $\mathcal{A}, \mathcal{D}$ and $\mathcal{S}$ respectively), through the exponential function, i.e. $\mathcal{S}(\tau, t) \triangleq e^{S(\tau,t)}$ etc. Note that although the queuing system in the SNR domain becomes *multiplicative*, the delay of the system remains as in the bit domain [14], i.e. we have $\mathcal{W}(t) = W(t)$. As with the MGF-based analysis approach, a bound ε for the delay violation probability $\Pr[W(t) > w^\varepsilon]$ can be derived based on a transform of the cumulative arrival and service processes in the SNR domain. In [14] it was shown that such a violation probability bound for a given w^ε must satisfy $\inf \{\mathcal{K}(s, t + w^\varepsilon, t)\} \leq \varepsilon$, where $\mathcal{K}$ is referred to as kernel function and consists of the sum of the product of the Mellin transform of the cumulative arrival and service process. The Mellin transform [15] of a non-negative random process $X(\tau, t)$ is defined as:

$$\mathcal{M}_{X(\tau,t)}(s) = \mathrm{E}\left[X^{s-1}(\tau, t)\right], s \in \mathbb{R}\,. \tag{1}$$

This approach is very interesting for wireless network performance analysis. As the network performance analysis is shifted into the physical layer, i.e. the SNR domain, the typical problem with obtaining the log-moment generating function (in the bit domain) of the effective capacity or MGF-based approach is not encountered anymore. Therefore, the need to abstract the channel using Markov chains is no longer necessary, allowing a much more detailed analysis of wireless systems with respect to their physical layer behavior. For example, a straightforward analysis of the Rayleigh-fading wireless communication channel is presented in [14]. Note in particular that the basic approach has been extended to arbitrary multi-hop systems by our own efforts in [JG21]. Summarizing, to date, the Mellin-transform based approach for *system-level* performance evaluation of wireless systems is the best analytical framework with respect to (i) level of detail regarding the physical layer behavior; (ii) its ability to analyze tail distributions of the delay and backlog; (iii) as well as its ability to analyze multi-hop transmission systems. Finally, note that only very few works exist which exploit this approach for system analysis so far [16][JG29].

3 Project Description

Future wireless networks are expected to provide very high reliabilities at very low latencies. For example, industrial automation requires latencies in the range of a few milliseconds (at most) while simultaneously requiring less than 10^{-8} delay violation probability. At the same time, safety-critical packets subject to such requirements might enter the network sporadically in case of event-based control. Naturally, these safety-critical applications also have very strict security requirements. To analyze such scenarios from a theoretical perspective, we need to bring modern approaches from stochastic network calculus together with recent results from information theory regarding blocklength-limited transmission and regarding security. The queuing perspective (i.e. network calculus approach) is required due to potential traffic variations from the new applications: While a system can be analyzed purely from the physical layer point of view (considering the maximum arrival rate of the source as constant arrival rate and then optimizing the delay-limited capacity, for example), this perspective always is subject to significant over-provisioning, leading ultimately to wrong system design conclusions (consider also resource sharing among several streams to increase utilization or multihop analysis). Due to the Melllin-transform based analysis approach discussed above, there is now a promising rigorous approach for wireless network queuing analysis. On the other hand, traditional information theoretic models analyze the information flow from an asymptotic point of view, i.e. asking for the maximum rate between a set of points with respect to an infinite decoding time horizon. However, it is apparent that for low latency applications such information theoretic models are not sufficient, as the infinite time horizon is clearly not practical. Recently, interesting bounds regarding blocklength-limited information transmission have been published [17], which are a much better starting point for the theoretical analysis of future wireless systems. In addition, to account for the security analysis, secrecy channel scenarios from information theory need to be analyzed with respect to their queuing performance. As a consequence, we propose to bring these approaches together (Mellin-transform based network calculus and blocklength-limited capacity models, or secrecy capacity) and investigate the resulting models with respect to the target requirements of future applications (low-latency, high reliability, security). In particular, we strive in this research to determine *limits* with respect to latency, reliability and secure rate, i.e. from a system-point-of-view under which conditions can certain requirements *not be met*. We will approach this goal by addressing the following work packages:

WP1: BL-limited Performance Model - 1.5 Years

The first work package addresses a queuing-theoretic model of blocklength-limited information transmission. Given this model, we will consider various system optimizations with respect to safety-critical low latency communications.

In their seminal work, Polyansky et al. [17] provide an approximate expression for the maximum possible information rate R of an AWGN communication channel, where the codewords have finite length n. This rate expression is given by

$$R\left(n,\epsilon\right) \approx \log\left(1+\gamma\right) - \sqrt{\frac{V}{n}} \cdot Q^{-1}\left(\beta\right) \text{ , with } V = 1 - \frac{1}{\left(1+\gamma\right)^2} \ . \tag{2}$$

In the above expression, γ denotes the average channel SNR, V is referred to as channel dispersion factor, n is the blocklength of the communication (as mentioned), and Q^{-1} is the inverse of the Gaussian Q-function. Note that the communication is subject also to an error rate β which is set by the transmitter. Hence, if decoding with a finite horizon n, the maximum unrestricted information flow (i.e. Shannon capacity) between two points is diminished by the channel dispersion, the decoding horizon and the probability that the transmitted information can not be decoded correctly.

Task 1.1 (6 months): The first step in this work package is to derive from the basic information-theoretic model (2) a stochastic service curve according to the Mellin-

transform based stochastic network calculus approach. For this, essentially the Mellin-transform (1) of the cumulative service process in SNR domain needs to be determined, where the instantaneous service increments (in bit domain) result from (2) (also assuming a certain distribution of the channel SNR γ, for example exponential or Nakagami-type fading). To date, this is an open problem. Apart from the mathematical difficulties, this step also involves the modeling of two random effects for the instantaneous service (the random rate R due to fading as well as the random loss of the frame). We have already obtained preliminary results on this task, which we describe further below in Section 5. In addition to the derivations, the work package also contains the validation of the analytical results by simulations. Note that with respect to the effective capacity blocklength-limited performance has been considered in [18]. However, the analysis is limited to single-hop systems with constant arrivals.
Task 1.2 (6 months): Given the established performance model, interesting trade-offs need to be addressed to study the limits of reliability under latency constraints. This translates into the optimization of the system performance in terms of delay violation probability. For perfect channel state information it is unclear how the transmitter should choose the error probability β per block to minimize the overall resulting delay violation probability. Should a constant error probability be chosen, and if so, how would that depend on the average channel SNR? This question must be generalized in a second step to unknown channel state information. How do optimal parameter choices look like, and what is the price to pay, in such a case? Which levels of latency and reliability in particular can not be met? Again, apart from the mathematical derivations, the work package also consists of the validation of the results by simulations. Note that the current research in the information theoretic domain uses outage capacity to characterize the limits of wireless communication systems regarding low latency applications [19]. As discussed above, this leads to significant over-provisioning, in particular for variable-rate sources.
Task 1.3 (6 months): Finally, we will address in this work package the question regarding the optimization over a multi-hop path. The Mellin-transform based stochastic network calculus approach provides recursive end-to-end performance bounds, as shown by our own previous work [JG21].. However, so far the approach has neither been considered with respect to optimization of the end-to-end delay performance, nor with respect to the blocklength-limited physical layer models of (2). Having said that, there are clear trade-offs in the allocation of the errors β and the block lengths n along a multi-hop route if a given delay target is defined. In this last task, we will be dealing with minimizing the end-to-end delay violation probability in such settings, based on the results of the previous two tasks.

WP2: Security Aspects - 1.5 Years

The second objective of this project is to investigate the system-level performance with respect to secure communications. From an information-theoretic perspective, the secrecy capacity of a system with one transmitter a, one receiver b and one eavesdropper e is given by:

$$C_s = [C_{a,b} - C_{a,e}]^+ = \left[\log\left\{\frac{1+\gamma_{a,b}}{1+\gamma_{a,e}}\right\}\right]^+ , \quad (3)$$

taking the traditional definition of Shannon capacity into account, i.e the secure information theoretic capacity is given by the differential capacity of the payload channel and the eavesdropper channel. Substituting the ratio between the two instantaneous SNRs in (3) by a single random variable z and assuming the two channels to be independently Rayleigh-fading, the resulting random variable has the probability density function:

$$f_Z(z) = \left(\frac{1}{\bar{\gamma}_{a,e}\cdot z + \bar{\gamma}_{a,b}} + \frac{\bar{\gamma}_{a,e}\cdot\bar{\gamma}_{a,b}}{\left(\bar{\gamma}_{a,e}z + \gamma_{a,b}\right)^2}\right)\cdot e^{-\frac{z-1}{\bar{\gamma}_{a,b}}} , \quad (4)$$

where $\bar{\gamma}$ denotes the average SNR of the corresponding links. Note in particular the close relationship between this information theoretic secrecy capacity model, and the distribution of the signal-to-interference-and-noise ratio (SINR), in case that communication is simply interfered by a single transmitter. In this case, the SINR distribution (assuming a single interferer and again Rayleigh-fading channels) turns out to be:

$$f_\gamma(x) = \left[\frac{\sigma^2}{\bar{p}_I x + \bar{p}_s} + \frac{\bar{p}_s\bar{p}_i}{\left(\bar{p}_i x + \bar{p}_s\right)^2}\right]\cdot e^{-\frac{\sigma^2 x}{\bar{p}_s}} , \quad (5)$$

where $\bar{p}$ denotes the average received power from the transmitter (subscript s) or from the interferer (subscript i).

Task 2.1 (9 months): In this work package, we will initially analyze the secrecy capacity model in the stochastic network calculus framework. In particular, the initial step is to find the corresponding service curve of the cumulative service process in SNR domain, given the bit domain instantaneous service increments as described by (4) (and independent randomly fading channels between the transmitter and the receiver/eavesdropper). For this, we have to determine the corresponding Mellin transform to subsequently obtain the corresponding kernel. Note that we have already achieved preliminary results on this as well, as discussed in Section 5. Furthermore, these results can be extended to the case of multiple eavesdropper. Finally, it is important to note that based on the network calculus related secrecy capacity analysis, we can also determine the stochastic service curve of interference-limited wireless communication systems. This results from the fact that the distributions of the service increments in SNR domain (i.e. the argument to the capacity formula) are very similar as given in (5) and (4). However, the analysis requires subtle changes in the Mellin transform, which we will address in this task as well. As with the previous work packages, apart from the mathematical analysis the achieved results will also be validated by simulations.

Task 2.2 (9 months): Apart from the above secrecy analysis, which essentially models the security aspects of a passive (eavesdropping) attacker, and attacker might also try to falsify information by actively sending information to the receiver. In that case, the receiver needs to authenticate the messages, for which different methods exist. Recently, authentication by physical layer information has received a significant amount of interest, where either channel characteristics can be exploited or characteristics of the transceivers (for example frequency offsets). The result is an interesting stochastic model of the packet reception process where - depending on the level of false negatives of interest - the receiver also rejects packets of the original source with a certain probability. A example analysis for frequency offset based authentication can be found for example in [JG24]. In this task the goal is to determine the corresponding Mellin-transform based service curve of the resulting service process in SNR domain. After establishing the basic model of a pure authentication process, we will also integrate the model with the secrecy channel from the previous section, to model active and passive attacks and characterize limits of the transmission with respect to such a combined attacker model. Note that the queuing analysis of such a physical-layer based authentication process is an open problem in the community.

WP3: Integrated Communication/Processing Paths - 1 Year
The last objective of the project is to extend the established models to so called integrated communication and processing paths. The intuition behind this objective is that future low latency systems will have to process application data along the communication path (instead of doing processing at the end of the paths, as it is today). For example, a safety-critical control loop requires the communication between sensor and controller as well as the communication between controller and actuator. However, at the controller there is also a processing step involved, which might be subject to delay variations (due to operation system scheduling etc.). In addition, at the controller a transformation of the sensor data is performed, such that potentially a different amount of data leaves the controller (in the direction of the actuator) in comparison to the amount of data coming into the controller (on a per-sample base). This violates the so called flow-conservation principle, and requires therefore a novel modeling approach. In this work package, we will combine the above models to such an integrated path performance model and study its limitation and trade-offs.
Task 3.1 (6 months): Initially, based on our results in [JG21], we will determine the stochastic service curve in SNR domain of a multi-hop communication path that integrates a processor element with varying service. The challenge here is to convert the stochastic processing characteristics of, for example, a virtual machine into a service increment that can be subsequently modeled in the SNR domain, ultimately determining the Mellin-transform. The processing model should also take the complexity of the processing task into account. Finally, the processing model needs to account for scaling, as input from a sensor of a certain size to a controller not necessarily leads to a command (at the controller) of the same size, which further complicates the analysis. In addition to the processing element to be considered, we are aiming at a model that integrates the blocklength-limited service of work package 1, while a second model shall integrate the security/interference effects considered in work package 2.
Task 3.2 (6 months): The final step in this work package relates to the study of optimal trade-offs in such an integrated model. Quite interesting options arise: Assuming for

example a variable allocation of transmit powers and processing capacity along the integrated path, which allocation leads to a minimization of the delay violation target? Up to which channel conditions can the processing element compensate for losses and latencies at the wireless links? We intend to investigate such optimization questions under the limiting point of view with respect to latency and reliability based on the model developed in Task 3.1.

4 Significance

The research pursued in this proposal strives to establish novel performance models that lay the foundation for future wireless network designs facing tough latency and reliability requirements on the one hand, and security constraints on the other hand. Due to random traffic sources, the need to analyze multi-hop transmission and the interest to study statistical multiplexing effects, we strongly advocate the study of these design problems based on a queuing-theoretic approach, namely Mellin-transform based stochastic network calculus. This approach is to date the most powerful one with respect to its tractability regarding wireless networks. However, the approach is mostly unexplored with respect to almost all contemporary design questions of wireless networks. By coupling this new approach with state-of-the art models from information theory, we are strongly convinced to contribute significantly to the theoretic networking and communication communities. Likewise, we expect our results to have practical relevance with respect to identifying hard latency/reliability limitations of future systems on the one hand, and security constraints on the other hand. We intend to disseminate these results through high-quality journals and conferences, primarily from IEEE.

5 Preliminary Results

The main applicant has worked for the last four years in the general area of queuing-theoretic modeling of wireless networks, primarily based on the effective capacity notion [JG8,JG34,JG37,JG41,JG43,JG46,] but also with respect to the Mellin-transform based stochastic network calculus [JG21,JG29] and adversarial queuing theory [JG25]. In addition, some more recent work has addressed the blocklength-limited capacity analysis especially of relaying systems [JG6,JG7]. General, more experimental experience with respect to low latency systems has been demonstrated (and awarded) in [JG19,JG23]. This serves as strong base for the proposed research. In addition, the main applicant has established an advanced PhD course on network calculus at KTH during the academic year 2014/2015 (together with H. Al-Zubaidy). During this course, several students have picked up project assignments, where one student has achieved preliminary results regarding WP1, while a second student has achieved preliminary result regarding WP2. For fading channels at finite blocklength, an approximation for the Mellin-Transform of the service process has been derived, which seems to work well at high SNR. Furthermore, we found a method to make this approximation tighter at low SNR, and we currently try to validate this approximation using Monte-Carlo simulations. These initial results give confidence that the envisioned goals can indeed be reached.

6 International and National Collaboration

Several researchers will be collaborating during the project with the main applicant. Naturally, the applicant has a very good collaborative base with respect to information-theoretic modeling and analysis within the Communication Theory department of KTH (Tobias Oechtering, Mikael Skoglund). A second very important collaboration partner is H. Al-Zubaidy (the author of the original Mellin-transform based stochastic network calculus paper), who is currently a researcher at KTH. He will be collaborating with the project team throughout the project duration. Further collaboration partners are M. Fidler from University of Hannover and J. Liebeherr from University of Toronto. Both are well known to the applicant, and will be tied into the project through research stays and student exchanges. Finally, the applicant is already co-supervising a PhD student at a research institute in Munich on Mellin-transform based stochastic network calculus (N. Petreska). She will therefore be a further, experienced collaboration partner. After her graduation in fall 2016, she plans to become post-doc and will be collaborating on the project topic.

6 References

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[7] R. Cruz, "A Calculus for Network Delay Part I: Network Elements in Isolation," *IEEE Trans. Inform. Theory*, vol. 37, no. 1, pp. 114–131, 1991.

[8] M. Fidler, "An End-to-End Probabilistic Network Calculus with Moment Generating Functions," in *14th IEEE International Workshop on Quality of Service, 2006*, June 2006.

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[10] M. Fidler, "A Network Calculus Approach to Probabilistic Quality of Service Analysis of Fading Channels," in *IEEE Globecom*, Nov 2006.

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[13] F. Ciucu, R. Khalili, Yuming Jiang, Liu Yang, and Yong Cui, "Towards a System Theoretic Approach to Wireless Network Capacity in Finite Time and Space," in *IEEE Infocom*, April 2014.

[14] Hussein Al-Zubaidy, Jörg Liebeherr, and Almut Burchard, "A (min, $\times$) Network Calculus for Multi-Hop Fading Channels," in *IEEE INFOCOM*, 2013.

[15] Brian Davies, *Integral Transforms and Their Applications*, Springer-Verlag, 1978.

[16] Hussein Al-Zubaidy and Jörg Liebeherr, "Service characterizations for multi-hop multiaccess wireless networks.," in *INFOCOM Workshops*, 2014, pp. 807–812.

[17] H. V. Poor Y. Polyanskiy and S. Verdu, "Channel coding rate in the finite blocklength regime," *IEEE Trans. Inform. Theory*, vol. 56, no. 5, 2010.

[18] M Cenk Gursoy, "Throughput analysis of buffer-constrained wireless systems in the finite blocklength regime," *EURASIP Journal on Wireless Communications and Networking*, vol. 2013, no. 1, pp. 1–13, 2013.

[19] Wei Yang, Giuseppe Durisi, Tobias Koch, and Yury Polyanskiy, "Quasi-static multiple-antenna fading channels at finite blocklength," *IEEE Transactions on Information Theory*, vol. 60, no. 7, pp. 4232–4243, 2014.

Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

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Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project

	Role in the project	Name	Percent of full time
1	Applicant	James Gross	20
2	Other personnel without doctoral degree	NN	80

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	2019	Total
1	Applicant	James Gross	20	230,000	240,000	250,000	260,000	980,000
2	Other personnel without doctoral degree	NN	100	670,000	709,000	750,000	790,000	2,919,000
	Total			900,000	949,000	1,000,000	1,050,000	3,899,000

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

	Type of premises	2016	2017	2018	2019	Total
1	Room costs	40,000	45,000	50,000	55,000	190,000
	Total	40,000	45,000	50,000	55,000	190,000

Running Costs

	Running Cost	Description	2016	2017	2018	2019	Total
1	Travel	International conference travels	15,000	30,000	30,000	30,000	105,000
	Total		15,000	30,000	30,000	30,000	105,000

Depreciation costs

Depreciation cost	Description	2016	2017	2018	2019

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	2018	2019	Total, applied	Other costs	Total cost
Salaries including social fees	900,000	949,000	1,000,000	1,050,000	3,899,000		3,899,000
Running costs	15,000	30,000	30,000	30,000	105,000		105,000
Depreciation costs					0		0
Premises	40,000	45,000	50,000	55,000	190,000		190,000
Subtotal	955,000	1,024,000	1,080,000	1,135,000	4,194,000	0	4,194,000
Indirect costs					0		0
Total project cost	955,000	1,024,000	1,080,000	1,135,000	4,194,000	0	4,194,000

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

The project will require the efforts of the main applicant (20% of his working time) plus the work of a PhD student (full time). The student will be newly recruited.
In addition, the project will benefit from senior PhD students helping in the work (in particular Sebastian Schiessl) without accounting for their working time in the budget. This is also true for the post-doc of the group (Muhammad Mahboob Ur Rahman).

The budget calculations are based on the following numbers:
Base salary of the PI: 52.000 Kr/month
Base salary of a PhD student: ~28.000 Kr/month

In addition to including taxes and social benefits, the given costs also account for the overhead at KTH with the following percentages from the gross salary:
KTH central: 23.6 %
EES school: 6.28 %
Department: 6.68 %

In addition to the given cost for personal, we also account for room costs (mainly for the new PhD student), as well as traveling costs. Regarding the travelign costs, the first year is calculated with a lower cost, due to the ramp-up phase in terms of publishing.

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	2018	2019

CV

1 Higher education qualifications

- December 2001: **Dipl.-Ing. (with distinctions) in Computer Engineering,** Technical University of Berlin, Germany.

2 Degree of Doctor

- June 2006: **Dr.-Ing. (with distinctions) in Electrical Engineering, Area: Wireless Networks,** Technical University of Berlin, Germany.
  Title of the thesis: "Dynamic Algorithms for Multi-User OFDMA Networks". Advisor: Prof. Adam Wolisz.

3 Postdoctoral positions

- 07/2006–12/2007: **Postdoc,** Technical University of Berlin, Germany.

4 Qualifications required for appointment as a docent

March 2015, KTH Stockholm

5 Present position, period of appointment, percentage of research in the position

- Since November 2012: **Associate Professor**, KTH Royal Institute of Technology, Department Communications Theory. 70% time devoted to research.

6 Previous positions and periods of appointment

- 01/2008–10/2012: **Assistant Professor**, RWTH Aachen University, Department of Computer Science.
- 01/2002 – 06/2006: **Research and Teaching Assistant**, Technical University of Berlin, Department of Electrical Engineering.

7 Interruptions

None.

8 Supervision

- Dr. Georg Kung, RWTH Aachen University (Main PhD supervisor). (2008 - 2013)
- Oscar Punyal, RWTH Aachen University (Main PhD supervisor). (2008 - 2014)
- Christian Dombrowski, RWTH Aachen University (Main PhD supervisor). (Started January 2010).
- Di Li, RWTH Aachen University (Main PhD supervisor). (Started June 2010)
- Donald Parruca, RWTH Aachen University (Main PhD supervisor). (Started Jujne 2010)
- Yulin Hu, RWTH Aachen University (MainPhD supervisor). (Started August 2011)
- Neda Petreska, ESK Munich (Co-Supervisor PhD). (Started September 2011)
- Mirko Stoffers, RWTH Aachen University (Main PhD supervisor). (Started June 2012)
- Sebastian Schiessl, KTH Royal Institute of Technology (Main PhD supervisor). (Started September 2013)
- Anwar Hithnawi, ETH Zurick (Co-Supervisor PhD). (Started March 2014)

- Sahar Imtiaz, KTH Royal Institute of Technology (Main PhD Supervisor). (Started March 2015)
- Muhammad Mahboob Ur Rahman, KTH Royal Institute of Technology (Post-Doc). (Started December 2013)

9 Other Merits

9.1 Honors and Awards

- 2015 **Best Demo Paper Award GI NetSys** for the paper ”EchoRing - Meting Hard Real-time Constraints with Decentralized Wireless Networks”.
- 2009 **Best Paper Award IEEE WoWMoM** for the paper ”Admission Control based on OFDMA Channel Transformations”.
- 2009 **Best Paper Award European Wireless** for the paper ”Optimal Power Masking in Soft Frequency Reuse based OFDMA Networks”.
- 2007 **VDE-ITG/GI-KuVS Ph.D. Thesis Award**, a German nationwide Ph.D. award jointly granted by the VDE and GI in the area of networking.
- 2002-2005 **Scholar of the Graduate School MAGSI**, a scholarship funded by the German national science foundation DFG.
- 2002 **Erwin-Stephan Price**, an award of TU Berlin for the best diploma degrees over all disciplines in the academic year 2001.
- 1999 **Education Abroad Scholarship**, a scholarship of TU Berlin for studying one year abroad, used to study in the graduate program of UCSD.

9.2 Conference and Journal activities

- **Organizing Committee Member (Publication Chair)**, ICST WiOpt 2008.
- **TPC Member (Selection)**: IEEE WoWMoM (2009 - 2015), ICST WiOpt (2007- 2013), ACM MSWiM (2011 - 2015), ACM SigComm (2006, 2007).
- **Workshop Organizer** for several national workshops and seminars in Germany on network simulation (2008 and 2011).

9.3 Other

- **Regular Scientific Reviewer**, for the German national science foundation (DFG), Fonds National (Luxembourg), QNRF (Qatar).
- **Ph.D. Thesis Opponent,** Linkoeping University (2014), Hannover University (2013), RWTH Aachen University (2012, 2013),
- **Member of the Ph.D. thesis committee of 8 other theses**.
- **Invited talks in conferences (Selection):** 2014 Workshop on Network Calculus, 2013 IEEE WoWMoM Workshop on Autonomic Networks, 2013 SNOW, 2010 European Wireless,
- **Invited Talks (Selection):** ETH Zurich (2014), Rice University (2014), Hannover University (2013), Uppsala University (2013), University of Porto (2012), Nanjing University (2011).

Publication list

1 Publication List 2007 – 2015 – James Gross

Citation data is based on Google Scholar database information and excludes self-citations. The five most important publications for the project are marked by (★).

1.1 Five Most Cited Publications

[JG1] W. Hu, D. Willkomm, L. Chu, M. Abusubaih, J. Gross, G. Vlantis, M. Gerla and A. Wolisz. "Dynamic Frequency Hopping Communities for Efficient IEEE 802.22 Operation," *IEEE Communications Magazine*, Special Issue: Cognitive Radios for Dynamic Spectrum Access, vol. 45, no. 5, pp. 80-87, 2007.
Number of citations: 200

[JG2] D. Willkomm, J. Gross and A. Wolisz. "Reliable Link Maintenance in Cognitive Radio Systems," In *Proc. IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySpan)*, November 2005.
Number of citations: 145

[JG3] M. Bohge, J. Gross, M. Meyer and A. Wolisz. "Dynamic Resource Allocation in OFDM Systems: An Overview of Cross-Layer Optimization Principles and Techniques," *IEEE Network Magazine*, Special Issue: Evolution towards 4G Wireless Networking, vol. 21, no. 1, pp. 53-59, 2007.
Number of citations: 125

[JG4] J. Gross, J. Klaue, H. Karl and A.Wolisz. "Cross-Layer Optimization of OFDM Transmission Systems for MPEG-4 Video Streaming," *Computer Communications*, vol. 27, no.11, pp. 1044-1055, 2004.
Number of citations: 85

[JG5] K. Wehrle, M. Günes, and J. Gross (Eds.). Modeling and Tools for Network Simulation. *Springer*, ISBN: 978-3-642-12330-6, 2010.
Number of citations: 80

1.2 Peer-reviewed Journal Papers

[JG6] Y. Hu, J. Gross and A. Schmeink. On the Performance Advantage of Relaying under the Finite Blocklength Regime. *IEEE Communication Letters*, accepted for publication, 2015. (★)
Number of citations: 0

[JG7] Y. Hu, J. Gross and A. Schmeink. On the Capacity of Relaying with Finite Blocklength. *IEEE Transactions on Vehicular Technology*, accepted for publication, 2015. (★)
Number of citations: 0

[JG8] Y. Hu, J. Gross and A. Schmeink. QoS-Constrained Energy Efficiency of Cooperative ARQ in Multiple DF Relay Systems. *IEEE Transactions on Vehicular Technology*, accepted for publication, 2015. (★)
Number of citations: 1

[JG9] A. Berger, J. Gross, T. Harks and S. Tenbusch. Constrained Resource Assignments: Fast Algorithms and Applications in Wireless Networks. *Management Science*, accepted for publication, 2015.
Number of citations: 0

[JG10] O. Puñal, C. Pereira, A. Aguiar and J. Gross, Experimental Characterization and Modeling of RF Jamming Attacks in VANETs. *IEEE Transactions on Vehicular Technology*, vol. 64, no. 2, pp. 524-541, 2015.
Number of citations: 1

[JG11] J. Gross and M. Reyer. Performance Prediction for OFDMA Systems with Dynamic Power and Subcarrier Allocation. *Computer Communications*, vol. 34, no. 8, pp. 973- 984, 2011.
Number of citations: 2

[JG12] F. Naghibi and J. Gross. Performance Prediction Model for Interference-limited Dynamic OFDMA Systems. *FREQUENZ: Journal of RF-Engineering and Telecommunications*, vol. 64, no. 9-10, pp. 159-164, 2010.

Number of citations: 0

[JG13] M. Bohge, J. Gross, and A. Wolisz. Optimal Soft Frequency Reuse and Dynamic Subcarrier Assignments in Cellular OFDMA Networks. *Transactions on Emerging Telecommunications Technologies*, vol. 21, no. 8, pp. 704?713, 2010.
Number of citations: 7

[JG14] J. Gross, M. Emmelmann, O. Puñal and A. Wolisz. Enhancing IEEE 802.11a/n with Dynamic Single-User OFDM Adaptation. *Elsevier Performance Evaluation Journal*, vol. 66, no. 3-5, pp. 240-257, 2009.
Number of citations: 6

[JG15] M. Abusubaih, S. Wiethoelter, J. Gross and A. Wolisz. A New Access Point Selection Policy for Multi-Rate IEEE 802.11 WLANs. *International Journal of Parallel, Emergent and Distributed Systems (IJPEDS)*, vol. 23, no, 4, pp. 291-307, 2008.
Number of citations: 16

[JG16] W. Hu, D. Willkomm, L. Chu, M. Abusubaih, J. Gross, G. Vlantis, M. Gerla and A. Wolisz. Dynamic Frequency Hopping Communities for Efficient IEEE 802.22 Operation. *IEEE Communications Magazine*, Special Issue: Cognitive Radios for Dynamic Spectrum Access, vol. 45, no. 5, pp. 80-87, 2007.
Number of citations: 200

[JG17] M. Bohge, J. Gross, M. Meyer and A. Wolisz. A New Optimization Model for Dynamic Power and Sub-Carrier Allocations in Packet-Centric OFDMA Cells. *FREQUENZ: Journal of RF-Engineering and Telecommunications*. Special Issue on Selected Papers of the 2006 International OFDM Workshop. vol. 61, no. 1-2, pp. 35-38, 2007.
Number of citations: 9

[JG18] M. Bohge, J. Gross, M. Meyer and A. Wolisz. Dynamic Resource Allocation in OFDM Systems: An Overview of Cross-Layer Optimization Principles and Techniques, *IEEE Network Magazine*, Special Issue: Evolution towards 4G Wireless Networking, vol. 21, no. 1, pp. 53-59, 2007.
Number of citations: 125

1.3 Peer-reviewed Conference Papers

[JG19] C. Dombrowski and J. Gross, "EchoRing: A Low-Latency, Reliable Token-passing MAC Protocol for Wireless Industrial Networks," In *Proc. of the European Wireless Conference 2015 (EW 2015)*, Budapest, Hungary, 2015.
Number of citations: 0

[JG20] D. Li, Z. Lin, M. Stoffers and J. Gross, "Spectrum Aware Virtual Coordinates Assignment and Routing in Multihop Cognitive Networks," In *Proc. of the 14th IFIP International Conference on Networking 2015 (Networking 2015)*, Toulouse, France, 2015.
Number of citations: 0

[JG21] N. Petreska, H. Al-Zubaidy, R. Knorr and J. Gross, "On the Recursive Nature of End-to-End Delay Bound for Heterogenous Networks," In *Proc. of the IEEE International Conference on Communications 2015 (ICC 2015)*, London, England, 2015. (★)
Number of citations: 0

[JG22] M. Rahman, A. Yasmeen and J. Gross, "A Distributed Relay Beamforming-enhanced TDMA System," In *Proc. of the IEEE Vehicular Technology Conference 2015 (VTC Spring 2015)*, Glasgow, Scotland, 2015.
Number of citations: 0

[JG23] C. Dombrowski and J. Gross, "EchoRing- Meeting Hard Real-time Constraints by Decentralized Wireless Networks", (Demonstrator paper), In *GI KuVS NetSys*, Cottbus, Germany, 2015.
Number of citations: 0

[JG24] M. Rahman, A. Yasmeen and J. Gross, "PHY Layer Authentication via Drifting Oscillators," In *Proc. of the IEEE Global Telecommunications Conference 2014 (GLOBECOM 2014)*, Austin, USA, 2014.
Number of citations: 0

[JG25] S. Tenbusch, C. Loeding, F. Radmacher and J. Gross, "Guaranteeing Stability and Delay in Dynamic Networks based on Infinite Games," In *Proc. of the IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS 2014)*, Philadelphia, USA, 2014.
Number of citations: 0

[JG26] M. Stoffers, R. Bettermann, J. Gross and K. Wehrle, "Enabling Distributed Simulation of OMNeT++ INET Modules," In *Proc. of the 1st OMNeT++ Community 2014*, Hamburg, Germany, 2014.
Number of citations: 0

[JG27] D. Parruca, F. Aizaz, S. Chantaraskul and J. Gross, "Semi-Static Interference Coordination in OFDMA/LTE Networks: Evaluation of Practical Aspects," In *Proc. of the ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems 2014 (MSWIM 2014)*, Montreal, Canada, 2014.
Number of citations: 0

[JG28] Y. Hu, J. Gross and A. Schmeink, "Outage Probability of a Multi-Relay Cognitive Network with an Uncertain Number of Forwarding Relays," In *Proc. of the IEEE International Symposium on Wireless Communication Systems (ISWCS 2014)*, Barcelona, Spain, 2014.
Number of citations: 0

[JG29] N. Petreska, H. Al-Zubaidy and J. Gross, "Power Minimization for Industrial Wireless Networks und Statistical Delay Constraints," In *Proc. International Teletraffic Conference 2014 (ITC)*, Karlskrona, Sweden, 2014. (★)
Number of citations: 1

[JG30] O. Puñal, I. Aktas, C. Schnelke, G. Abidin, J. Gross and K. Wehrle, "Machine Learning-based Jamming Detection for IEEE 802.11: Design an Experimental Evaluation," In *Proc. of the 14th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2014 (WoWMoM 2014)*, Melbourne, Australia, 2014.
Number of citations: 1

[JG31] D. Parruca and J. Gross, "On the Interference as Noise Approximation in OFDMA/LTE Networks," In *Proc. of the IEEE International Conference on Communications 2014 (ICC 2014)*, Melbourne, Australia, 2014.
Number of citations: 1

[JG32] M. Stoffers, G. Kunz, J. Gross and K. Wehrle, "Large-Scale Network Simulation: Leveraging the Strengths of Modern SMP-based Compute Clusters," In *Proc. of the 7th International ICST Conference on Simulation Tools and Techniques 2014 (SIMUTools 2014)*, Lissabon, Portugal, 2014.
Number of citations: 0

[JG33] D. Parruca, M. Grysla, S. Goertzen and J. Gross, "Analytical Model of Proportional Fair Scheduling in Interference-limited OFDMA/LTE Networks," In *Proc. of the IEEE Vehicular Technology Conference 2013 (VTC Fall 2013)*, Las Vegas, USA, 2013.
Number of citations: 6

[JG34] Y. Hu, J. Gross, A. Schmeink and T. Wang, "Maximizing Energy-Efficiency for Multiple Decode-and-Forward Relay System with QoS Constraints," In *Proc. of the IEEE International Symposium on Wireless Communication Systems (ISWCS 2013)*, Ilmenau, Germany, 2013.
Number of citations: 1

[JG35] O. Puñal, H. Zhou and J. Gross, "RFRA: Random Forests Rate Adaptation for Vehicular Networks," In *Proc. of the 13th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2013 (WoWMoM 2013)*, Madrid, Spain, 2013.
Number of citations: 2

[JG36] C. Dombrowski, N. Petreska, S. Görtzen, A. Schmeink and J. Gross, "Energy-Efficient Multi-Hop Transmission for Machine-to-Machine Communications," In *Proc. of the 11th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks 2013 (WiOpt 2013)*,

Tsukuba Sciene City, Japan, 2013.
Number of citations: 1

[JG37] M. Weyres and J. Gross, "Effective Service Capacity Analysis of Interference-Limited Multi-Carrier Wireless Systems," In *Proc. of the European Wireless Conference 2013 (EW 2013)*, Guildford, England, 2013.
Number of citations: 0

[JG38] D. Parruca, M. Grysla, H. Zhou, F. Naghibi, M. Petrova, P. Mähönen and J. Gross, "On Semi-Static Interference Coordination under Proportional Fair Scheduling in LTE Systems," In *Proc. of the European Wireless Conference 2013 (EW 2013)*, Guildford, England, 2013.
Number of citations: 1

[JG39] Y. Hu, J. Gross and Z. Ding, "The Outage Performance of Realtime Transmission in Multiple Asynchronous Relays Enhanced OFDM System," In *Proc. of IEEE Workshop on Computing, Networking and Communications (in conjunction with IEEE ICNC 2013)*, San Diego, USA, 2013.
Number of citations: 0

[JG40] D. Parruca and J. Gross, "Rate Selection Analysis under Semi-Persistent Scheduling in LTE Networks," In *Proc. of IEEE International Conference on Computing, Networking and Communications 2013 (ICNC 2013)*, San Diego, USA, 2013.
Number of citations: 4

[JG41] Y. Hu and J. Gross, "On the Outage Probability and Effective Capacity of Multiple Decode-and-forward Relay System," In *Proc. of IFIP Wireless Days 2012*, Dublin, Ireland, 2012.
Number of citations: 4

[JG42] D. Li and J. Gross, "Distributed TV Spectrum Allocation for Cognitive Cellular Network under Game Theoretical Framework," In *Proc. of the IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks 2012 (DySPAN 2012)*, Washington, USA, 2012.
Number of citations: 3

[JG43] J. Gross, M. Weyres and A. Wolisz, "Effective Service Capacity Analysis of Opportunistic Multi-Carrier OFDMA Systems," In *Proc. of the ACM International Symposium on QoS and Security for Wireless and Mobile Networks (ACM Q2SWinet 2012)*, Paphos, Cyprus, 2012.
Number of citations: 1

[JG44] F. Schmidt, A. Hithnawi, O. Puñal, J. Gross and K. Wehrle, "A Receiver based 802.11 Rate Adaptation Scheme with On-Demand Feedback," In *Proc. of the IEEE International Symposium on Personal, Indoor and Mobile Radio Communications 2012 (PIMRC 20012)*, Sydney, Australia, 2012.
Number of citations: 2

[JG45] O. Puñal, A. Aguiar and J. Gross, "In VANeTs we Trust? Characterizing RF Jamming in Vehicular Networks," In *Proc. of the 9th ACM Workshop on VehiculAr Inter-NETworking, Systems and Applications 2012 (ACM VANET 2012)*, Low Wood Bay, England, 2012.
Number of citations: 11

[JG46] J. Gross, "Scheduling with Outdated CSI: Effective Service Capacities of Optimistic vs. Pessimistic Policies," In *Proc. of the 20th IEEE/ACM Workshop on Quality of Service 2012 (IWQoS 2012)*, Coimbra, Portugal, 2012.
Number of citations: 1

[JG47] G. Kunz, D. Schemmel, J. Gross and K. Wehrle, "Multi-Level Parallelism for Time- and Cost-efficient Parallel Discrete-Event Simulation on GPUs," In *Proc. of the 26th ACM/IEEE Workshop on Principles of Advanced and Distributed Simulation 2012 (PADS 2012)*, Zhangjiajie, China, 2012.
Number of citations: 6

[JG48] O. Puñal and J. Gross, "Power Loading: Candidate for Future WLANs?," In *Proc. of the 13th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2012 (WoWMoM 2012)*, San Francisco, USA, 2012.
Number of citations: 1

[JG49] G. Kunz, M. Stoffers, J. Gross and K. Wehrle, "Know Thy Simulation Model: Analyzing Event Interactions for Probabilistic Synchronization in Parallel Simulations," In *Proc. of the 5th International ICST Conference on Simulation Tools and Techniques 2012 (SIMUTools 2012)*, Desenzano, Italy, 2012.
Number of citations: 4

[JG50] G. Kunz, S. Tenbusch, J. Gross and K. Wehrle, "Extending the OMNeT++ Sequence Chart for Supporting Parallel Simulations in Horizon," In *Proc. of the 5th International ICST Conference on Simulation Tools and Techniques 2012 (SimuTools 2012)*, Desenzano, Italy, 2012.
Number of citations: 0

[JG51] O. Puñal and J. Gross, "Combined Subcarrier Switch Off and Power Loading for 80 MHz Bandwidth WLANs," In *Proc. of the 18th IEEE International Workshop on Local and Metropolitan Area Networks 2011 (LANMAN 2011)*, Chapel Hill, USA, 2011.
Number of citations: 4

[JG52] X. Zhu, Z. Ding, O. Puñal and J. Gross, "Design and Implementation of Baseband Algorithms for OFDM-based Wireless Communication Systems," In *Proc. of the 7th IEEE International Conference on Wireless Communications, Networking and Mobile Computing 2011 (WiCom 2011)*, Wuhan, China, 2011.
Number of citations: 0

[JG53] G. Kunz, S. Tenbusch, J. Gross and K. Wehrle, "Predicting Runtime Performance Bounds of Expanded Parallel Discrete Event Simulations," In *Proc. of the 19th Annual Meeting of the IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems 2011 (MASCOTS 2011)*, Singapore, 2011.
Number of citations: 2

[JG54] D. Li and J. Gross, "Robust Clustering of Ad-hoc Cognitive Radio Networks under Opportunistic Spectrum Access," In *Proc. of the IEEE International Conference on Communications 2011 (ICC 2011)*, Kyoto, Japan, 2011.
Number of citations: 17

[JG55] O. Puñal, H. Escudero and J. Gross, "Performance Comparison of Loading Algorithms for 80 MHz IEEE 802.11 WLANs," In *Proc. of the IEEE Vehicular Technology Conference 2011 (VTC Spring 2011)*, Budapest, Hungary, 2011.
Number of citations: 6

[JG56] C. Dombrowski and J. Gross, "Reducing Outage Probability over Wireless Channels Under Hard Real-Time Constraints," In *Proc. of the 1st Workshop on Real-Time Wireless for Industrial Applications 2011 (RealWin 2011)*, Chicago, USA, 2011.
Number of citations: 0

[JG57] G. Kunz, M. Stoffers, J. Gross and K. Wehrle, "Runtime Efficient Event Scheduling in Multi-threaded Network Simulation," In *Proc. of the 4th International ICST Conference on Simulation Tools and Techniques 2011 (SIMUTools 2011)*, Barcelona, Spain, 2011.
Number of citations: 1

[JG58] G. Kunz, O. Landsiedel, J. Gross, S. Götz, F. Naghibi and K. Wehrle, "Expanding the Event Horizon in Parallelized Network Simulations," In *Proc. of the 18th Annual Meeting of the IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems 2010 (MASCOTS 2010)*, Miami, USA, 2010.
Number of citations: 8

[JG59] J. Gross, F. Radmacher and W. Thomas, "A Game-Theoretic Approach to Routing under Adversarial Conditions," In *Proc. of the 6th IFIP International Conference on Theoretical Computer Science 2010 (TCS 2010)*, Brisbane, Australia, 2010.
Number of citations: 1

[JG60] A. Eisenblätter, H. F. Geerdes, J. Gross, O. Puñal and J. Schweiger, "A Two-Stage Approach to WLAN Planning: Detailed Performance Evaluation Along the Pareto Frontier," In *Proc. of the 8th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks*

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Number of citations: 80

CV

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Research education

Dissertation title (swe)
Dynamic Algorithms for OFDMA-based Wireless Networks

Dissertation title (en)
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Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20204. Telekommunikation	-	2006-06-15

Publications

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Gross, James has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.