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研究課題名（和文）Study of Joint Optimization of Quality of Service/Experience and Security for Differentiated Services in 5G Heterogeneous Networks

研究課題名（英文）Study of Joint Optimization of Quality of Service/Experience and Security for Differentiated Services in 5G Heterogeneous Networks

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研究成果の概要（和文）：　超高密度スモールセルを使用した5Gネットワーク等の次世代のモバイルネットワークでは，信頼性と安全性の両方を高いレベルで提供することを目指しているため，ネットワーク事業者に負担がかかる．本研究の目的は，サービス品質とセキュリティレベルのバランスをとるため，問題を定式化し，解決するための適切な方法を提案することである．
　本研究内容は，国際学会やインパクトファクターの高いIEEEジャーナルに提出され，高い成果を上げることが出来た．

研究成果の学術的意義や社会的意義
Our proposal provided much higher QoS with higher security rank compared to conventional approaches By attending international meetings and workshops, the proposal was shared with peers to attract potential collaboration and also signify the contribution from Japan.

研究成果の概要（英文）：In the next-generation mobile network settings, for instance 5G networks with ultra-dense small cells, the network operators are burdened with the anticipation to provide both highly reliable and secure services to the users. Due to the contrasting goals of quality of service performance and security, it is critical to first model and analyze the traffic models carefully and then consider a balanced integration. The purpose of this research is to formulate this problem of finding a balanced set of tunable Quality of Service/Experience and security levels, and propose appropriate methods to optimally solve the problem.
Mature results were obtained and published in both international flagship conferences and the more analytically intensive papers submitted to the high impact factor IEEE journals/transactions. Deep learning based methods were demonstrated to be effective for intelligently routing packets in the wireless/mobile backbone network and fronthaul.

研究分野：情報通信ネットワーク

キーワード：QoS　QoE　Security　5G　IoT　ネットワーク

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９、ＣＫ－１９（共通）

１．研究開始当初の背景

For next-generation networks, Quality of Service/Experience and security are equally important because the users require both. However, security measures such as encryption, authentication, and so forth on the mobile devices may lead to significant impact on the network service performance. This problem becomes more difficult in joint core and small cell network. The security impact on the performance at the small cells becomes a bottleneck to the overall performance of the core network. So it is important to consider optimal traffic routing in the core network as well as traffic allocation in the small cells at the first stage. Then, it is essential to probe the intricate relationship between Quality of Service/Experience and security both at the small cells and the core network to devise optimal solutions.

２．研究の目的

The purpose of this research is to analyze the contrasting goals of Qulaity of Service performance and security in next-generation mobile networks, formally construct the tradeoff problem, and then propose appropriate methods to optimally solve the problem.

３．研究の方法

The proposal was developed and evaluated based upon the framework designed in the preceeding years. The UEs of small-cell-based HetNets aim to maximize both their QoS and security requirements in a selfish manner. QoS and security provisioning have some contrasting objectives, which makes it difficult for an eNB to provide UEs with optimized QoS for real-time differentiated services with different security demands. In this article, a joint optimization problem of QoS and security was formulated, and a game-theoretic algorithm was proposed to solve the problem. Our proposal allows the UEs to obtain the best possible quality of secure service levels while meeting their demanded QoS. At the same time, the eNB is able to maximize its bandwidth utilization. Simulation results demonstrated that our proposal provided much higher QoS (in terms of throughput, delay, and timeliness) with higher security rank compared to conventional approaches By attending international meetings and workshops, the proposal was shared with peers to attract potential collaboration and also signify the contribution from Japan. Through survey and literature review, we found deep learning to be a suitable method to find the balanced set of QoS and security levels.

４．研究成果

Mature results were obtained and published in both international flagship conferences and the more analytically intensive papers submitted to the high impact factor IEEE journals/transactions.

We evaluated the performance of average throughput, average delay, security rank of UEs, and maximum number of UEs with guaranteed timeliness on application. For comparison, several contemporary bandwidth allocation methods were used.

Figure 1(a) demonstrates the average throughput of the UEs linked to the same eNB. The result shows that with increasing numbers of UEs, they face increasing competition to obtain adequate bandwidth under their competitive QoS budgets and security demands. Hence, the quantity of allocated bandwidth per UE decreases, which in turn affects the average throughput of the UEs. The average throughput of the no security approach is highest due to no encryption, and could be considered as the theoretical maximum in this simulation. However, the no security approach is perceived as high risk for the UEs. On the other hand, in the Conventional1 method, all the UEs only choose one algorithm and a specific key size. Because the throughput is dependent on encryption time and key size, the Conventional1 approach causes severely low throughput for the UEs. In the case of the Conventional2 method, the UEs execute a random security algorithm from the given pool of algorithms supported by both the UEs and the eNB. The drawback of this method is that if UEs obtain the highest-level algorithm, the encryption time is significantly long. Therefore, it also causes poor throughput. Although the result of our proposal is slightly lower than the no security (i.e., theoretically maximum) case, it ensures adequate security levels (which is explained in the remainder of the section). Additionally, our proposal achieves the best results compared to the other conventional approaches because it allows the eNBs to optimally allocate the resource to the UEs based on their type of applications and security constraints.

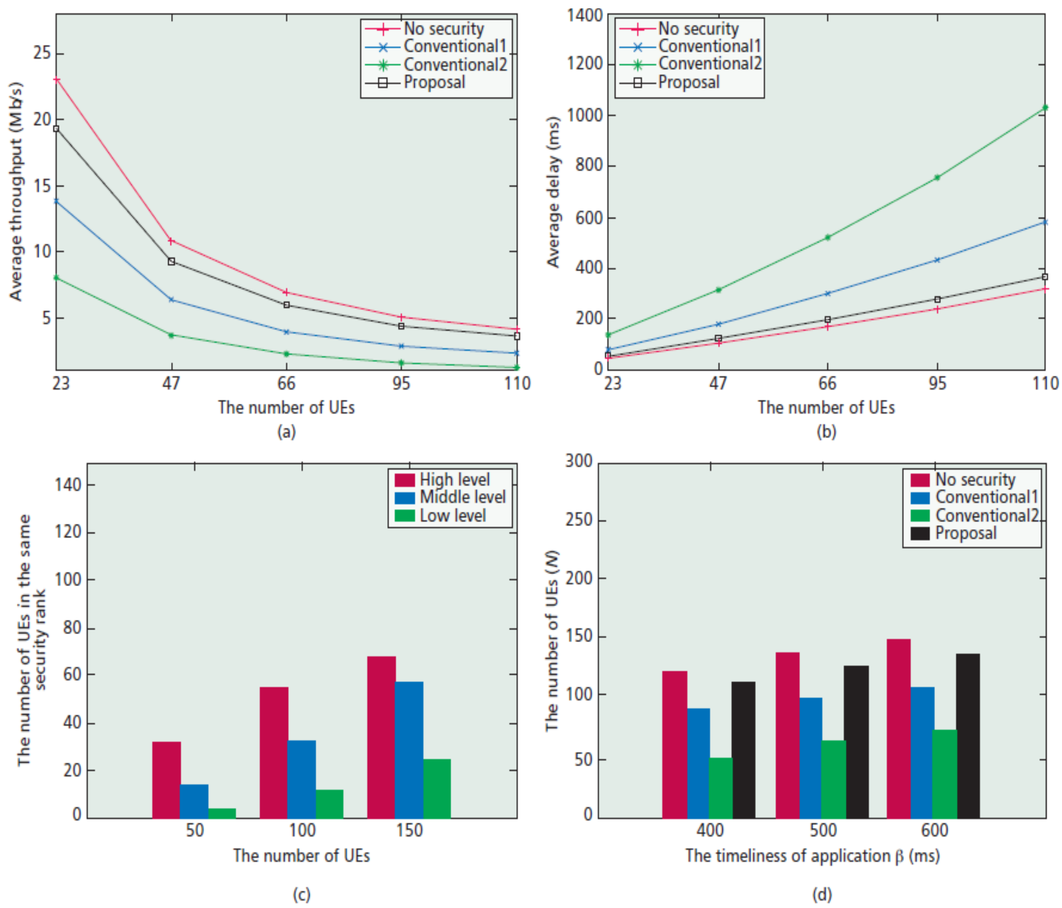

Fig 1. Results in terms of average throughput, average delay, security ranks of UEs, and the maximum number of UEs receiving desired timeliness of applications: a) comparison of average throughput in our proposal and other conventional methods; b) comparison of average delay in our proposal and other conventional methods; c) security ranks of UEs for various numbers of UEs; d) maximum number of UEs with timeliness of applications in our proposal and other conventional methods.

Figure 1(b) demonstrates the average delay experienced by the UEs. Increasing numbers of UEs need to compete with others to obtain bandwidth. Moreover, some bandwidth is spent transmitting some control information. Hence, more UEs cause less total bandwidth that can be distributed for data transmission; this causes delay increase. Because in the no security method all the UEs do not have the encryption time, which is a part of delay, the delay incurred in this case is the best one. However, again in a real HetNet, this case can only be regarded as an ideal model. Our proposal can help the UEs to choose the appropriate security algorithm and key size according to the rank of application. It is the reason that the increasing ratio of delay of our proposal is the lowest in contrast to the other conventional methods, and
the closest to that of the ideal model. From Figs. 4a and 4b, we can find that our result is close to the no security case. Hence, all eNBs and UEs will accept this result. In other words, eNBs and UEs cannot find another assignment so as to increase their utilities. It means that the obtained result using our proposal leads to Nash equilibrium.

Next, Figure 1(c) represents the number of UEs in the same security rank. In our model, the UEs with high-priority applications (e.g., VoLTE) can first decide the bandwidth. With increasing number of UEs, more UEs choose high levels and much bandwidth so as to minimize delay. However, the total bandwidth is fixed, which causes an increasing ratio of high level. Moreover, more competition causes higher jitter. This is the other reason the UEs choose high levels.When the number of UEs increases, more control information between the eNBs and the UEs is transmitted. Hence, the UEs face more severe competition. Because bandwidth has been occupied by the high-priority UEs, with the remaining bandwidth decreasing, other UEs have to choose middle or even low rank so as to maximize their utility. As a consequence, the increasing ratios of the middle and low ranks are greater than that of the high level.

Figure 1(d) demonstrates the maximum number of UEs with satisfied timeliness of application.
From the result, it can be concluded that compared to the other two conventional methods, our proposal can help more UEs share the same eNB. In other words, using our proposal, the maximum capacity of an eNB can be utilized. It can help a mobile operator to make critical decisions on how many eNBs should be deployed in the target area, and how much maximum capacity should be set.

Furthermore, our additional results in more mature publications demonstrated that deep learning methods, based on the training data obtained from the aforementioned proposal, were more effective for intelligently routing packets in the wireless/mobile backbone network and fronthaul.

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