Self-optimisation of admission control and handover parameters in LTE

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Abstract—In mobile cellular networks the handover (HO) algorithm is responsible for determining when calls of users that are moving from one cell to another are handed over from the former to the latter. The admission control (AC) algorithm, which is the algorithm that decides whether new (fresh or HO) calls that enter a cell are allowed to the cell or not, often tries to facilitate HO by prioritising HO calls in favour of fresh calls. In this way, a good quality of service (QoS) for calls that are already admitted to the network is pursued. In this paper, the effect of self-optimisation of AC parameters on the HO performance in a long term evolution (LTE) network is studied, both with and without the self-optimisation of HO parameters. Simulation results show that the AC parameter optimisation algorithm considerably improves the HO performance by reducing the amount of calls that are dropped prior to or during HO.

Index Terms—LTE, Radio resource management, Admission control, Handover, Optimisation, SON.

I. Introduction

In cellular networks like long term evolution (LTE), the handover (HO) algorithm decides when calls of users that move from one cell to another are handed over from the former to the latter. Calls that are handed over too late risk to be dropped as they advance further into a neighbouring cell and radio conditions will worsen until the connection can no longer be maintained. Because the HO algorithm selects a suitable moment and target cell for call HOs, it has an important impact on the quality of service (QoS) that will be experienced by the end users.

The admission control (AC) algorithm decides whether a new call that enters a cell, either because it is freshly started within the cell or it is handed over from another cell, is admitted to the cell or not. The algorithm bases its decisions on the amount of resources that is needed to guarantee the required QoS of the new call and the amount of resources that are (or can be made) available. Like HO, AC plays an important role in achieving the desired QoS of the end users. It ensures that the QoS of existing calls is maintained by rejecting incoming calls for which sufficient resources are not available.

In order to enhance the performance of networks and to make networks react to changes in e.g. traffic, mobility or environment characteristics, self-organising network (SON) techniques are developed by network vendors and third-party providers. SON allows the network to react on changes more autonomously (i.e. without human intervention) by automatically tuning network parameters.

A. Related work

AC algorithms for cellular networks have been described and studied in many papers. Several of these algorithms are based on a concept known in the literature as 'guard channels' [1]. Because ongoing calls that are dropped are experienced more as a nuisance by users than fresh calls that cannot be started, AC algorithms based on this concept try to facilitate HOs by giving HO calls priority over freshly started calls. The automatic adaptation of the parameters of AC algorithms in order to optimise performance has been studied in papers like [2], [3]. These algorithms aim at enhancing the acceptance of new calls while guaranteeing the QoS of existing calls. HO optimisation algorithms like the ones presented in [4], [5] try to optimise the HO parameters such that either the QoS is improved or the overhead for the network operator is lowered.

Self-optimisation in wireless networks is investigated in many research papers [6], [7], projects like SOCRATES, MONOTAS and E³ and industrial lobbies like next generation mobile networks (NGMN) promote the development of SONs.

In this paper, the influence of a SON algorithm that automatically tunes the parameters of an AC algorithm on the HO performance of the network is investigated. The influence of the algorithm will be investigated both with and without the presence of an algorithm that self-optimises the HO performance. The remainder of this paper is structured as follows: in Section II the AC, AC parameter optimisation, HO and HO parameter optimisation algorithms that are considered are described. The simulation environment and scenarios that are used are discussed in Section III. The results of the simulations are presented and analysed in Section IV. Finally, in Section V conclusions are drawn.

II. Algorithms

A. Admission control

The AC algorithm that is considered in this paper, is based on the well-known guard channels algorithm, see e.g. [1]. The algorithm distinguishes between calls that are handed over from neighbouring cells (HO calls) and calls that are freshly started in the cell (fresh calls) and prioritises the HO calls over fresh calls. By doing this calls that need to be handed over can do so easier which lowers the risk that they are dropped because of poor radio conditions as they move further away from their source cell into another cell. When a call arrives, the AC algorithm checks whether there is sufficient unused cell capacity left in order to admit the call. A HO call is admitted to the cell if the cell capacity that is used by all other active calls (c^*) plus the capacity required by the HO call (c_{req}) does not exceed the estimated cell capacity (C) at that time. I.e. a HO call is accepted when Equation 1 holds. A fresh call is admitted to the cell if the cell capacity that is used by all other active calls plus the capacity required by the new call does not exceed a predefined fraction (Th_{HO}) of the cell capacity at that time. I.e. a fresh call is accepted when Equation 2 holds. The Th_{HO} parameter has a value between 0 and 1.

$$c^* + c_{\mathrm{req}} < C \qquad (1)$$
$$c^* + c_{\mathrm{req}} < Th_{\mathrm{HO}} * C \qquad (2)$$

The capacity of an LTE cell varies over time. This is because LTE uses adaptive modulation and coding (AMC) meaning that the modulation and coding scheme (MCS) that is used to service each user varies over time, depending on the quality of the radio link between the user equipment (UE) and the eNodeB (eNB). To estimate the cell capacity, the technique described in [3] is used. The estimate is based on measurements of the number of bits that can be sent in a certain time interval, according to the assignment of scheduling resources by the packet scheduler.

The Th_{HO} parameter allows a trade-off to be made between allowing many fresh calls and risking the rejection of a relatively high number of HO calls (high Th_{HO}) or rejecting a relatively high number of fresh calls and giving more priority to the acceptance of HO calls (low Th_{HO}). The Th_{HO} parameter also has an influence on the QoS of ongoing calls: if a large part of the cell capacity is reserved for HO calls, there will be fewer instances where, due to the varying cell capacity, the cell capacity becomes lower than the capacity required for the ongoing calls than when only a small amount of the cell capacity is reserved. The selected setting of Th_{HO} should be based on an operator policy that expresses the desired trade-off between call admission and QoS. An example of such a policy is to minimise rejecting calls while placing minimum requirements on selected QoS metrics.

B. Admission control parameter optimisation

The Th_{HO} parameter of the AC algorithm is automatically tuned by the AC parameter optimisation algorithm in order to use the available network resources as efficiently as possible while guaranteeing a good QoS. This algorithm tries to ensure that there is always sufficient capacity for incoming HO calls. The need for tuning this threshold arises from various changes that occur during operation like an elevated number of incoming HO calls or a varying cell capacity.

The optimisation algorithm operates by collecting measurements during observation intervals. These are repeating intervals with a fixed length. At the end of each of these intervals the AC optimisation algorithm decides whether or not to adapt the Th_{HO} parameter and in which direction. The measurements that are collected by the AC parameter optimisation algorithm are (1) the rejection ratio of the fresh calls (RRFC), (2) the rejection ratio of the handover calls (RRHOC), which are respectively the fraction of the fresh and HO calls that are rejected by the AC algorithm; (3) the traffic loss ratio (TLR) which is the amount of guaranteed bit rate (GBR) (see Section III-A) traffic that is lost due to buffer overflows at the eNB because there are not sufficient resources to send all incoming data to the user and (4) the low throughput ratio (LTR) which is the fraction of the non real-time calls that do not achieve their requested throughput over their entire duration.

The goal of the AC parameter optimisation algorithm is to make these measurements as low as possible. Since there is a trade-off between the RRFC on the one hand and the RRHOC, TLR and LTR on the other hand, it will, however, not always be possible to make them all small enough at the same time especially in situations where the load is high. In this case the algorithm will prioritise pursuing a low RRHOC, TLR and LTR over a low RRFC.

When either the RRHOC, the TLR or the LTR exceed predefined thresholds, set by the operator, Th_{HO} is decreased by a fixed amount. In this way, more resources are reserved for HO calls. If the RRHOC, TLR and the LTR are all below their thresholds, while the RRFC exceeds a predefined threshold, Th_{HO} is raised in order to allow fresh calls to use resources that were previously reserved for HO calls. Otherwise Th_{HO} remains unchanged.

C. Handover

The HO procedure controls when active calls switch from one serving cell to another. A sequence diagram depicting the procedure is shown in Figure 1. The HO procedure is initiated by the UE sending a measurement report (MR) to the source eNodeB (SeNB), containing a list of neighbouring eNodeBs (NeNBs) that are eligible for HO (step 1). When the SeNB receives the MR, it chooses a HO target for the UE (step 2). Then, the SeNB sends a HO requests to the target eNodeB (TeNB) (step 3) which decides whether the call is admitted to that cell or not according to the procedure described in Section II-A (step 4) and notifies the SeNB of its decision (step 5). If the TeNB admits the call, the SeNB will send a HO command to the UE (step 6) which will then perform the HO (step 7).

The sending of the MRs by the UE to the SeNB is controlled by two parameters: hysteresis and time-to-trigger
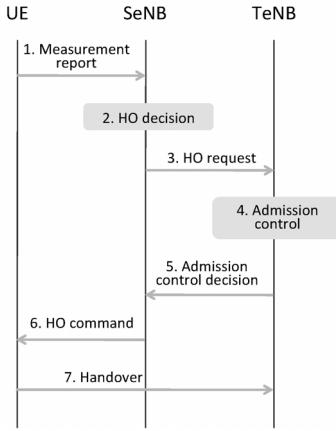
Fig. 1: A sequence diagram showing the steps of the HO procedure.

(TTT), which are together referred to as the handover operating point (HOP). These parameters respectively determine how big the difference between the reference symbol received power (RSRP) of the serving cell and target cell must be and how long this difference must be this high before a MR is sent. Figure 2 illustrates the hysteresis and TTT.
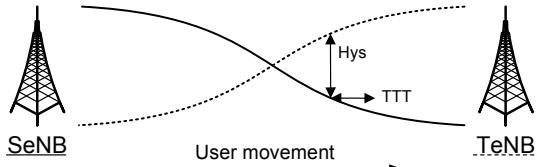

Fig. 2: Hysteresis and TTT

The MR triggering at the UE is standardised [8], while the selection of the TeNB is done by the SeNB and is implementation-specific. The following approach is used in this paper: for every active call, the SeNB will always be in one of the following two states: either it has issued a HO request to a TeNB for that call, and it is waiting for the AC decision from that cell, or it is waiting for a target cell to become available such that it can issue a HO request for the call towards that cell. When the SeNB issues a HO request towards a TeNB, AC is performed at the TeNB.

If the TeNB accepts the HO call, the SeNB sends a HO command to the UE. In case the TeNB rejects the HO call, the SeNB will start a timer for that cell which will expire after a constant amount of time. Before that timer expires, no new HO request for that UE towards that TeNB will be issued again, because it is very likely that it will be rejected again anyway. However, the SeNB will issue a HO request to another TeNB, if an eligible one is available. A neighbour cell is called eligible for the HO of a UE if it is present in the list of HO targets the SeNB received in the most recent MR from the UE, and if no timer is running for that cell. If more than one eligible neighbour is available, the SeNB issues the HO request to the eligible neighbour for which the UE has reported the highest RSRP value in the most recent MR. If no eligible neighbour is available, the SeNB will wait until one becomes available, either because it receives a new MR that contains a new HO target cell for which no timer is running, or because the timer for one of the target neighbour cells expires, and that neighbour is still present in the most recent list of HO targets the SeNB received from the UE. Note that the SeNB will not stop a running timer for a neighbour cell that is no longer present in the list with HO targets it receives from the UE in a MR, as it might happen that this cell will be present again in a next MR. After a TeNB has accepted the HO call and the SeNB has sent the HO command to the UE, the SeNB removes the timers and the list of TeNBs kept for that UE.

D. Handover parameter optimisation

In order to optimise the HO performance, the HO parameter optimisation algorithm automatically adapts the HOP [9]. The adaptation of the HOP is based on two metrics: the call drop ratio (CDR) and the ping-pong handover ratio (PPHOR). The CDR is the fraction of calls that are dropped due to bad radio conditions relative to the total amount of calls that enter a cell, either because they are handed over or because they are freshly started within that cell. The PPHOR is the fraction of calls that are handed back to a cell from which they were handed over within a certain amount of time called the ping-pong critical time T_{crit} which is 5 seconds. Call drops are undesirable because they influence the user experience negatively. Ping-pong HOs are undesirable because an increased number of HOs causes signalling overhead. Each time a call makes a HO there is also a period (between the AC decision and the actual HO, see Figure 1) where there is an overlap of resource allocation in both the SeNB and TeNB. When a HO is performed, the risk of packet loss is also higher since LTE uses hard HO and the UE will be disconnected from the eNB for a short time.

The HO parameter optimisation algorithm adapts the HOP by maintaining a direction (increasing or decreasing) in which the HOP should be updated. Each time the HOP is updated, either the hysteresis or the TTT is changed in the current optimisation direction, alternating between both. The hysteresis is adapted in steps of 0.5 dB, the TTT is adapted by changing to the next higher or lower value in the sequence of possible TTT values [8]. The HOP is adapted on equally spaced time instances. The period between these instances is called a HO observation interval. During these intervals, values for the CDR and PPHOR are collected. At the end of the interval, a weighted sum of these values is calculated and that value is compared to the value of the previous interval. If the current value is lower than the previous one, i.e. the HO performance is better, the HOP is updated in the current optimisation direction. If the current value is higher than the previous value, i.e. the HO performance is worse, the optimisation direction is reverted and the HOP is changed in that direction. In this way the HO optimisation algorithm will change the HOP in the direction for which the weighted sum becomes lower. The weights that are used to calculate the weighted sum reflect the

policy set by the operator. In this paper, a weight of 2 for the CDR and 0.5 for the PPHOR is used.

III. SCENARIOS

In order to assess the influence of the AC parameter optimisation on the HO performance, scenarios in which this influence can be studied are defined. These scenarios are simulated in a dynamic system-level simulator created using OPNET Modeler.

A. Simulation environment

The simulation area features 25 eNBs with omnidirectional antennas, placed on an equally spaced 5×5 grid. Users move around in the simulation area at a constant velocity and according to a random walk mobility model. During a simulation, users alternate between inactive and active states. When a user is in the active state it is performing a call. For simplicity, users can only make one call at a time. The time between two successive calls, i.e. the time the user is in the inactive state, is drawn from an exponential distribution with a mean that is referred to as the idle duration. The time that the user is in the active state depends on the type of call. There are two types of calls: GBR calls and non-GBR calls which correspond to the two types of bearers in LTE. The GBR calls are subdivided in voice and video calls. Voice calls are characterised by an average bit rate of 6.1 kbit/s (12.2 kbit/s with a 50% activity factor), video calls by an average bit rate of 64 kbit/s [10]. GBR calls are modelled as fluid flows, i.e. continuous bit streams ignoring the discrete packet nature, at the average bit rate. Since GBR calls deliver a continuous flow of data and have stringent delay constraints, traffic is considered to be lost when GBR calls do not receive the average amount of resources that they require. GBR calls have durations that are drawn from exponential distributions, after which they become inactive again. Non-GBR calls do not have a predetermined duration but instead have a certain amount of data that needs to be sent, and is determined as described in [10]. Non-GBR calls end after all data has been sent. Although there is not a hard limit on the bit rate that is required for the calls, the throughput is considered to be too low when the calls do not achieve the bit rate that was reserved for them, i.e. 250 kbit/s. When a user becomes active, it randomly chooses the type of call. Voice, video and non-GBR calls are all chosen with a probability of $\frac{1}{3}$.

The eNB of each cell features scheduling rules that determine how many resources are assigned to each active user in a certain time interval. The scheduling policy prioritises GBR traffic over non-GBR traffic. Scheduling decisions are based on the number of resources that are required by each user which is influenced by the type of call and the path loss towards the user. Path loss calculations are performed using the Okumura-Hata model for large urban areas. Furthermore, shadow fading that is both auto-correlated in time and cross correlated with the shadow fading of other antennas is considered [11], fast fading is not considered. A summary of the simulation parameters can be found in Table I.

TABLE I: A summary of the simulation parameters.

# subchannels	25	Prop. model	OH large urban
Antenna model	omnidir.	Shadowing std.	8 dB
Avg. video dur.	3 min	eNB Tx power	43 dBm
Avg. voice dur.	1.5 min	UE height	1.5 m
Base freq.	2.6 GHz	Video rate	64 kbit/s
Bw/subch	180 kHz	Voice rate.	1 kbit/s
Corr. coeff.	0.5	eNB height	30 m
Decorr. dist.	33 m	S2S distance	500 m

B. Scenario description

In order to investigate the influence of AC optimisation on the HO performance, scenarios were defined in which interventions of the optimisation algorithms are likely. Since self-optimisation is introduced such that networks can adapt to changes in the environment, all studied scenarios contain at a certain point in time a change in either the UE velocity, the load or both.

User velocity has an impact on both AC and HO. When the UE velocity increases the signal level of the SeNB may degrade too fast and calls may be dropped before they are handed over. The UE velocity affects AC indirectly: when more calls are dropped, the load will be lower and there will be fewer HO calls and relatively more fresh calls. The load mainly has an influence on AC. When the load is high there will be less resources available which will cause that less calls can be accepted.

A summary of the scenarios that were simulated can be found in Table II. In the simulations both gradual as well as abrupt changes in UE velocity and load are studied. Gradual changes start after 6300 seconds (1 hour 45 minutes) of simulation time. After this time, in case the load increases, the idle duration is decreased linearly over a time span of 1800 seconds (30 minutes) such that the load rises from a value that corresponds to a RRFC of 2% to a value that corresponds to a RRFC of 20%. In case the load decreases, the reverse occurs. In case the UE velocity increases it is increased linearly from 3 km/h to 50 km/h, also after 6300 seconds and during 1800 seconds. Again, in case of a load decrease, the reverse happens. After 8100 seconds (2 hours 15 minutes) of simulation time the load and the UE velocity are kept constant again at their new value. Abrupt changes occur after 7200 seconds (2 hours).

The (initial) HOP is set to 4dB for the hysteresis and 480 ms for the TTT which, for a UE velocity of 3 km/h, corresponds to a CDR of 0.5%. The (initial) Th_{HO} is set to 0.8.

IV. SIMULATION RESULTS

In this section, simulation results for one of the scenarios are presented in detail, after which the similarities and differences for the other scenarios are discussed briefly. All scenarios were simulated for four different cases: (1) with neither of the optimisation algorithms enabled, (2) with only the AC parameter optimisation algorithm enabled (3) with only the HO parameter optimisation algorithm enabled and (4) with both the AC and HO parameter optimisation algorithms enabled. The different cases are always compared in pairs:

case 1 is compared with case 2 and case 3 is compared with case 4. In this way the effect of AC parameter optimisation can be studied both with and without the presence of the HO parameter optimisation algorithm.

TABLE II: A summary of the simulated scenarios.

#	Change	Velocity		Load	
		Before	After	Before	After
1	Gradual	3 km/h	50 km/h	2% RRFC	
2	Abrupt	3 km/h	50 km/h	2% RRFC	
3	Gradual	3 km/h		2% RRFC	20% RRFC
4	Abrupt	3 km/h		2% RRFC	20% RRFC
5	Gradual	3 km/h	50 km/h	2% RRFC	20% RRFC
6	Abrupt	3 km/h	50 km/h	2% RRFC	20% RRFC
7	Gradual	50 km/h	3 km/h	20% RRFC	2% RRFC
8	Abrupt	50 km/h	3 km/h	20% RRFC	2% RRFC

A. Scenario where the UE velocity and the load are increased gradually

In this section, the results of the scenario where the UE velocity and the load change gradually (Scenario 5) are presented and discussed in detail. All results are shown in Figure 3. The period in which the increase in UE velocity and load occurs is marked with a grey rectangle.

Figure 3a shows the evolution of the RRFC. As can be seen from the no optimisation curve, the load increases such that the RRFC rises from 2% to 20%. The same happens in case only the HO parameter optimisation is enabled. As can be seen from the AC optimisation and the AC and HO parameter optimisation cases, the RRFC is higher in case the AC parameter optimisation algorithm is enabled.

The reason for the higher RRFC can be seen in Figure 3b. This figure shows the RRHOC. During the change RRHOC rises due to the increased load. In the cases where the AC optimisation algorithm is enabled, the RRHOC is however quickly restored to the same level as before the change. This is the trade-off that is made by the AC parameter optimisation algorithm: in case of high load the RRHOC will remain low at the cost of a higher RRFC.

The reason for the prioritisation of HO calls by the AC algorithm is to reduce calls drops. By reserving capacity for HO calls, HO calls are more easily accepted by a cell. This way, a SeNB will sooner find a TeNB that accepts the HO call, which reduces the probability that a HO call is dropped. The fact that a lower RRHOC effectively lowers the CDR can be seen in Figure 3c. In this figure, after the increase in UE velocity and load, the CDR is clearly lower in the cases where the AC parameter optimisation algorithm is enabled than in the corresponding cases where it is not. In the cases where the HO parameter optimisation algorithm is *not* enabled, the CDR is on average 12% without AC parameter optimisation and 8.6% with admission control optimisation. In the cases where the HO parameter optimisation algorithm *is* enabled, the CDR is on average 4.7% without AC optimisation and 2.7% with AC optimisation. Note also that if the HO parameter

optimisation algorithm is enabled, the CDR is lower than in the corresponding case where it is not.

When looking at the PPHOR in Figure 3d, it can be seen that it starts to rise after the change. The observed higher number of ping-pong HOs is explained by the fact that due to the faster UE velocity users move faster through the patches where, due to shadow fading, the RSRP of the SeNB will be higher than that of the TeNB and vice versa. This will increase the possibility of a HO back to the previous cell within the ping-pong HO critical time. The AC parameter optimisation algorithm does however not influence the PPHOR as the values of the corresponding cases with and without AC parameter optimisation are nearly identical. The values of the cases with and without HO parameter optimisation are however different since this is a trade-off of the lower CDR that is a result of the HO optimisation algorithm. So the benefit of the AC parameter optimisation on the CDR does not negatively influence the PPHOR.

The positive influence of the AC parameter optimisation algorithm on the traffic loss can be seen in Figure 3e: the traffic loss ratio is lower when the AC parameter optimisation algorithm is enabled than in the corresponding case where it is not. The difference between the corresponding cases is however rather small. This is because at all times the AC algorithm tries to assure that the QoS of the ongoing calls is guaranteed. The AC parameter optimisation algorithm cannot improve on this much. There is however a more noticeable difference between the cases where the HO parameter optimisation algorithm is enabled and the cases where it is not. In case the HO parameter optimisation algorithm is enabled, the TLR is higher. This is because when the HO parameter optimisation algorithm is enabled the PPHOR ratio is higher because the HO optimisation algorithm reduces the CDR at the expense of a higher PPHOR and, since HOs increase the risk of traffic loss, a higher PPHOR causes a higher TLR.

B. Other scenarios

In the other scenarios where either the UE velocity or the load increase gradually, AC optimisation has a similar effect on the HO performance as in the scenario that was discussed in Section IV-A: the CDR is lower in case AC optimisation is enabled than in the corresponding case where it is not, especially when the UE velocity and/or the load are high. The effects are however much less pronounced in the scenarios where either only the UE velocity or only the load are high. This is because in case only the UE velocity is high, most HO calls will be accepted by the first NeNB and AC is not very important. In case only the load is high but the UE velocity is low, there will be fewer HO calls which does not require Th_{HO} to be adjusted much after the change. When the UE speed and/or the load start at a high value and decrease during the simulation (scenarios 7 and 8), the same observations before the change can be made as in the corresponding scenarios with an increase in UE velocity or load after the change and vice versa. When there is an abrupt change in UE velocity and/or load the results are the same except for a small period after the

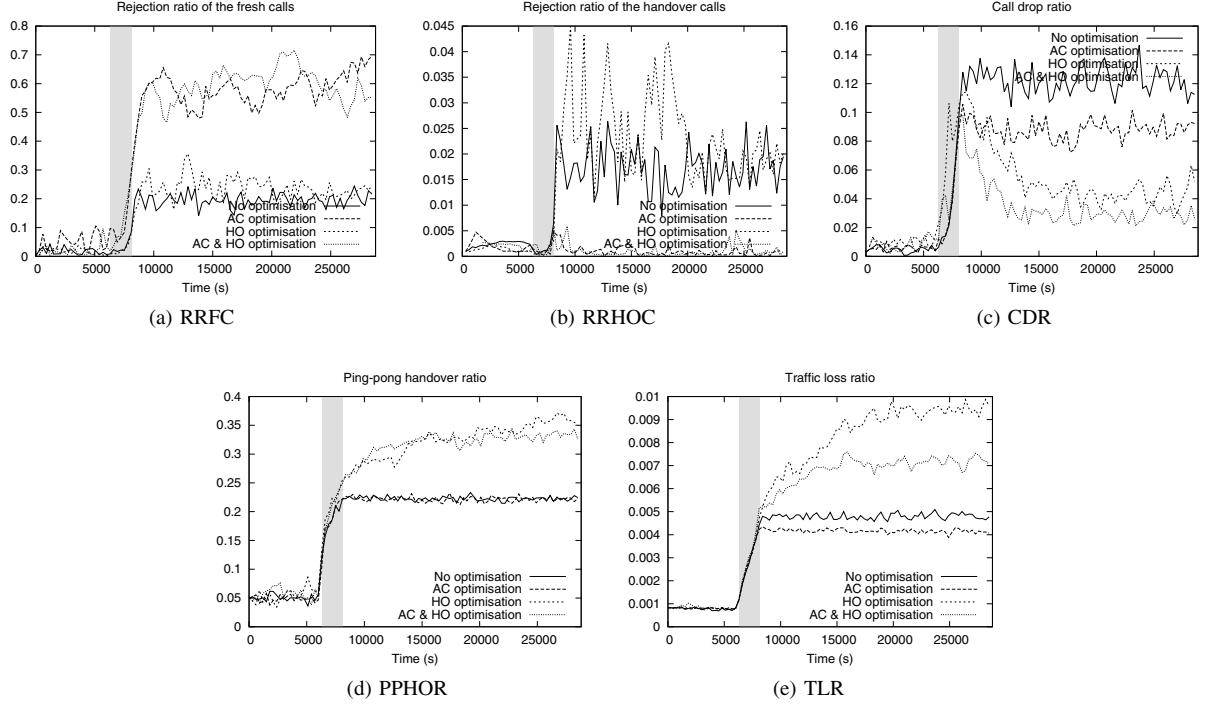(a) RRFC   (b) RRHOC   (c) CDR

(d) PPHOR   (e) TLR

Fig. 3: The AC and HO performance metrics of scenario 5, plotted over time.

change in which, in case of an abrupt change it takes a certain amount of time before the optimisation algorithms manage to reach a steady state, as would be expected.

V. CONCLUSIONS

In this paper, the influence of AC parameter optimisation on the HO performance in an LTE network was studied. In order to study this interaction a simulation environment was presented in which a scenarios featuring changes of the UE velocity and/or the load were simulated. The interaction is studied both with and without the presence of a HO parameter optimisation algorithm in order to verify whether this influences the results.

Simulation results show that AC parameter optimisation clearly has a beneficial influence on the HO performance of a network. Since the AC parameter optimisation algorithm tries to reduce the RRHOC by reserving sufficient resources for HO calls, these calls are more easily admitted to a cell. This avoids that calls that need to perform a HO have to try multiple target cells before being accepted and more often can pick the best HO target which reduces the risk that a call is dropped due to bad radio conditions. This results in a considerable lower CDR. Simulation results also show that the AC optimisation algorithm does not act differently in the presence of an algorithm that optimises the HO parameters: when a HO optimisation algorithm is enabled, the AC optimisation algorithm even manages to improve the HO performance even more.

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