Roadrunner: O-RAN-based Cell Selection in Beyond 5G Networks

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***Abstract*—O-RAN is currently emerging as the way to build a virtualized 5G and beyond Radio Access Network (RAN) that is based on open interfaces and off-the-shelf hardware. O-RAN consolidates the intelligence of several gNodeBs at the Near-realtime RAN Intelligent Controller (RIC) making it more programmable and aware of the mobile users' surroundings. In this paper we present *Roadrunner*, an O-RAN-based solution designed to improve cell selection in 5G and beyond networks. Our work has been motivated by the fact that the legacy cell selection procedure in both 4G and 5G networks tends to prefer radio quality and seamless connectivity to high data rates. The reason for this can be traced back to the older releases of the mobile network architecture that were optimized for the circuit-switched communication paradigm and for sparse network deployments. However, with an O-RAN-based approach we can leverage the global network view built and maintained by the Near-realtime RIC to jointly optimize mobility management for channel quality *and* bitrate. We have designed *Roadrunner* following the O-RAN Alliance design principles and without requiring any change to the existing 3GPP signaling. No changes to the mobile devices are required either. Performance measurements carried out on a small scale testbed show how *Roadrunner* can almost double the median throughput in some specific traffic scenarios while also achieving better network fairness.**

***Index Terms*—Software-Defined Networking, O-RAN, 4G/5G, Mobility Management, Cell-selection, Handoff**

I. Introduction

Mobile Network Operators (MNOs) have witnessed a huge increase in mobile data traffic demand over the last few years. In particular, it is expected that by 2023 there will be more that 13 billion mobile devices generating more than 49 exabytes per month [1]. In order to accommodate such an increase in mobile connectivity demands, the MNOs are utilizing several strategies. First, the transition to the 5G network has begun, and older networks are progressively being converted to the new standard. Second, more cells are being deployed in order to increase network density. Third, newer frequency bands are being explored, e.g. mmWave.

While deploying the latest version of the mobile network architecture allows us to tap into a series of technological advances, e.g. newer air interfaces, larger bandwidth, more efficient modulation and coding schemes, it is equally important to make full use of both the already, and soon to be available, network resources. This is particularly true in the case of 5G networks in that they require costly upgrades across the MNO's entire infrastructure, thus increasing the need to make optimal use of the available resources, i.e., the over-provisioning of resources is not a choice. In particular, it is important that users are associated to the network cells that provide the best performances and not just the best radio connectivity, even when a candidate cell with better performance is available. Evidence of such behavior for operational networks can be found in [2].

As mentioned in the article cited above, such cases are not rare in reality. For example, a mobile device can get stuck with lower data rates even when cells that could offer a performance that is up to an order of magnitude higher can be found in the network. The reason behind this behavior can be found in the way the serving cell is selected in current (including 5G) mobile networks. Due to several backwards compatibility constraints, cell selection is performed in such a way as to ensure that every mobile device is associated to a good cell and not necessarily the best one as long as a sufficient network performance can be delivered. This is part of the legacy of previous generations of the mobile network architecture, in which seamless connectivity and a stable cell selection was preferred to frequent changes. Moreover, older network were sparser and more homogeneous than current ones. This translates into fewer handoff possibilities and, in general, the fact that almost all cells had similar characteristics in terms of, for example, available bandwidth. Conversely, modern networks are considerably denser and more heterogeneous, with few large macrocells overlapping with many smaller ones. This means that modern mobile devices have significantly more handoff possibilities, and that the various cells can differ significantly in terms of available bandwidth, from small cells with just 5MHz to larger ones with 100MHz.

In order to tackle this and similar problems several efforts have been made in the last few years to make the mobile network more flexible and more programmable. In particular, the O-RAN Alliance has emerged as an industry-driven effort to make the Radio Access Network (RAN) more open, intelligent, and interoperable. This has been done by using the concept of Control-User Plane Separation (CUPS) in the mobile RAN, and by introducing a two-layer Software-Define RAN (SD-RAN) controller architecture featuring a control loop for near-real-time operations and a control loop for non-real-time operation. The proposed architecture draws a clear line between control and management, and allows the deployment of resource allocation features as *xApps* on top of a programmable controller. In order to enable this innovation, the O-RAN alliance has defined a new series of interfaces between the newly introduced controller and the standard elements of the mobile network architecture, so the O-RAN architecture should be considered as an extension of the 3GPP architecture rather than a parallel effort.

In this paper we present *Roadrunner* as an O-RAN compliant way to address the under-utilization issues highlighted above. *Roadrunner* has three main design requirements. First, as opposed to [2], it aims at improving cell association by taking into account the radio quality and the bandwidth of the cell, as well as the user distribution. Second, it is completely compatible with the current 3GPP signaling, yet at the same time it requires that the basestations (eNBs and gNBs) support the new interfaces defined by the O-RAN Alliance, in particular the E2 interface. Third, as it is completely network driven no changes are required to the UE, which can continue to assist the network in implementing the cell selection procedure by performing the required network measurements when instructed by the serving basestation.

We have implemented *Roadrunner* using off-the-shelf components and open-source platforms. In particular, we use a modified version of srsRAN [3] to implement the RAN and *5G-EmPOWER* [4] as a near-real-time RAN Intelligent Controller (RIC). The evaluation performed on a small scale testbed shows that the proposed approach can almost double the median throughput in some specific traffic scenarios while also achieving better network fairness. It is worth noting that, while the evaluation was carried out with a 4G RAN, the approach proposed is generation-agnostic and the under-utilization issues that are targeted by this work apply to 4G and 5G networks alike. We have released part of the software stack used in the work under a permissive APACHE 2.0 license for non-commercial use[1].

The structure of the paper is the following. The related work is discussed in Sec. II. In Sec. III we provide some background information on radio access. The motivation behind this work is presented in Sec. **??**. Sec. IV discusses the system design and the proposed cell-selection algorithm while the implementation details and the results of the evaluation are the focus of Sec. V. Finally, Sec. VI concludes the paper and suggest some future research directions.

II. Related Work

A sizable body of literature has been published on user association and load balancing in cellular networks [5], [6], [7], [8], [9], [10]. A load– and QoS–aware user association is considered in [5]. In [6], a traffic offloading scheme that jointly considers power control and user association is proposed. A joint cell association and resource allocation problem is presented in [7]. To reduce the computational complexity of the proposed algorithm, a fractional user association scheme is suggested in which it is assumed that users can be associated with more than one cell. In [8] a data-driven self-tuning algorithm for traffic steering is proposed to improve the overall Quality of Experience (QoE) in multi-carrier 4G networks. The results show that the proposed algorithm significantly improves upon the QoE figures obtained with classical load balancing techniques. In [9] the authors propose a data-driven approach for managing and forecasting handovers for a huge number of cells. A load-balancing algorithm for traffic steering in single tier networks using an adaptive controller with reinforcement learning is presented in [10].

Similarly, the literature on handover management is equally significant [11], [12], [13], [14]. In [11], a handover scheme considering UE speed and requested service is proposed to manage mobility between macro/small cells. The results show how the proposed scheme can increase network capacity while enforcing the required QoS. A velocity-aware handover management scheme for two-tier downlink cellular networks is proposed in [12]. The results highlight the handover rate problem in dense cellular environments and show the importance of the proposed handover schemes. In [13], an association scheme that jointly maximizes downlink system capacity and minimizes mobile station uplink transmit power is presented. A fuzzy-logic-based self-tuning strategy with reinforcement learning is proposed in [15] to adjust inter-RAT handover margins to reduce the call dropping ratio in heterogeneous LTE networks. Finally, a survey of handover management solutions for multi-tier LTE networks is presented in [14].

Another category of work looks into the reason underlying poor performance in cellular networks [16], [17], [18]. In [16] the authors study handover misconfiguration in 3G/4G networks, showing how it can lead to persistent loops, where the device oscillates between cells even without radio link and location changes. The authors of [17] study how the configuration parameters affect the handoff performance and user data access, and conclude that the handoff decision can have a serious impact on end-user performance. A similar study is conducted by the authors of [18].

Our work takes its inspiration from the above studies which focus on studying the problem underlying poor performance and proposes a practical solution that uses state-of-the-art technologies and solutions. Our work is different from the above studies in two ways. First, we look for a practical solution that can be used in real networks. Second, we are the first to use an O-RAN-inspired solution for cell selection in 4G/5G networks.

III. Background

In this section we provide some background on radio access in mobile networks. In particular, we first introduce such concepts as cells, carrier frequency, and bandwidth. Then we explain what Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ) are. Finally, we describe how the cell selection procedure is performed.

Cells and component carriers. Base-stations (eNBs and gNBs) are the physical devices providing mobile devices with radio access. Each base-station is composed of one or more cells, which are logical entities operating on continuous blocks of spectrum called component carriers. A component carrier can have different bandwidths (1.4, 3, 5, 10, 15, and 20 MHz). Each cell is identified by a Physical Cell Id (PCI), and the cell(s) to which a mobile terminal is attached at any given moment is called the serving cell set, which is composed of a primary cell and possibly multiple secondary cells. Carrier aggregation is a technique which increases the data rate per

[1]On-line resources available at: https://5g-empower.github.io

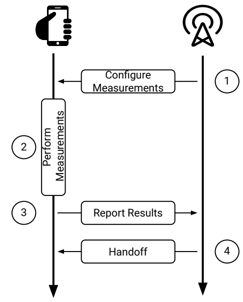


Fig. 1. 3GPP Cell selection procedure.

user by assigning multiple component carriers to the same user, i.e. multiple secondary serving cells.

RSSI/RSRP/RSRQ/RSSI. RSRP and RSRQ are measurements of signal level and quality for 4G/5G networks. They are used in particular to perform handoff in cellular networks. When a mobile terminal moves from one cell to another and performs cell selection or cell reselection, it has to measure the signal strength/quality of the neighboring cells. In the handoff procedure the LTE specification provides the flexibility of using RSRP, RSRQ, or both. Downlink reference signals are transmitted for each antenna port in specific OFDM symbols. The carrier Received Strength Signal Indicator (RSSI)) measures the average total received power observed only in OFDM symbols containing reference symbols for antenna port 0. The RSSI measurement is taken over the full bandwidth while the RSRP is narrow–band. In the RSRQ the number of Physical Resource Blocks (PRBs) used is also considered.

Cell selection. A mobile terminal serving cell is selected from among a number of candidate cells. Figure 1 depicts a high-level view of the 3GPP cell (re)selection procedure (for the sake of simplicity many details are omitted). During cell (re)selection, the network controls the quality measurements for cells to be (re)selected. The mobile device measurements are triggered by the base-station according to the serving cell RSRP/RSRQ levels. The measurements must satisfy different requirements in terms of RSRP/RSRQ before they are reported to the serving cell. As depicted in Figure 1, the procedure consists of four steps. During the first step the serving cell defines the criteria to trigger the measurements and reporting, e.g., if A is the serving cell, a possible criterion for triggering measurements could be: $RSRQ(A) < -15dB$ or $RSRP(A) < -122dBm$. During the second step the mobile terminal performs the measurements on candidate cells, and if such measurements satisfy the conditions set during step one, e.g., $RSRQ(A) < RSRQ(other) - 3dB$, then a UE measurement report is generated. In the fourth and final step the network decides, on the basis of some internal policy, whether a handoff should be performed, and if this is the case, it starts the necessary signaling to (re)select the serving cell.

IV. *Roadrunner* Design

In this paper we introduce *Roadrunner* as a means to tackle the under utilization problem that originates from the legacy cell selection scheme utilized by current 4G/5G networks. Note how *Roadrunner* is designed to achieve better resource utilization by selecting cells that are characterized by higher channel bandwidth rather than by improving the raw transmission of the information of the air interface. As a result *Roadrunner* improves the way resources are distributed but does not make new resources available. No special measurement or new signaling is needed by *Roadrunner*, and the traditional signaling shown in Fig. 1 can be reused (with tuned parameters). *Roadrunner* is compatible with the standard 3GPP mechanisms and requires no change to mobile terminals. However on the network side, the adoption of an O-RAN architecture is required, which is by no means an easy task, although several MNOs and vendors have started to look with increased interest into such a solution, and it is not unlikely that it will be deployed in commercial networks within a five years timeframe.

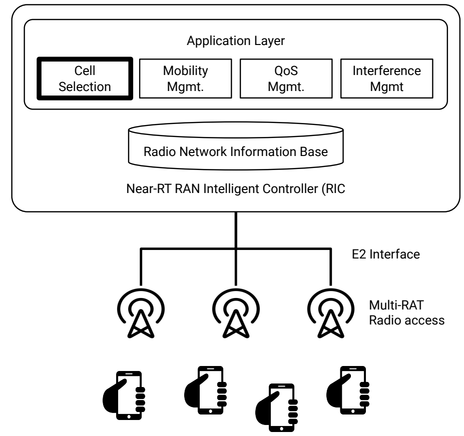


Fig. 2. *Roadrunner* components and interfaces.

A. *Overview of Roadrunner*

Figure 2 depicts the main components and interfaces of *Roadrunner*. As can be seen, the architecture is aligned with O-RAN and centered around the logically centralized near-real-time RAN Intelligent Controller (near-RT RIC), which is a central element of the O-RAN architecture. It collects the RAN state at the Radio Network Information Base (RNIB) and exposes it to the control applications, termed *xApps*, running on top of it. The near-RT RIC operates at a timescale between 10ms and 1s, thus allowing the implementation of several control policies (including cell selection) with the exception of MAC or PHY level policies, for which sub-ms granularity is required. A multi Radio Access Technology (RAT) RAN operates below the near-RT RIC and is interfaced to it through the E2 Interface. The RNIB stores both static and runtime information about the RAN. Among the static information we may have the geographical position, the antenna setup, etc., while the runtime information includes such data as traffic counters, mobile terminals measurements, etc. The RNIB is essentially a comprehensive snapshot of the network status collected by the near-RT RIC from several basestations.

In this paper we propose a solution in which a centralized *xApp* running on top of the near-RT RIC makes the handoff decision. A high-level representation of the signaling involved

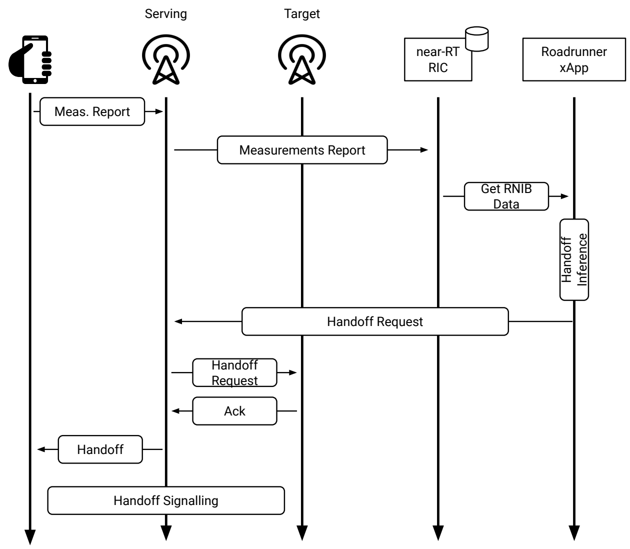


Fig. 3. *Roadrunner*-based cell selection signaling.

is shown in Fig. 3. In the envisioned scheme the measurements performed by the mobile terminal are, as required by standard 3GPP signaling, dispatched to the serving cell. However, instead of being used locally to make a handoff decision, they are forwarded to the near-RT RIC, where they are stored in the RNIB. This information stored at the RNIB constitute the context upon which the *Roadrunner xApp* operates in order to make the optimal handoff decision (referred to as *Handoff inference* in the figure). After the handoff decision is taken, a notification is sent to the serving cell, which then starts the required signaling procedure to implement the handoff.

B. Bandwidth-aware cell selection

The cell (re)selection procedure is established in TS 38.304 of 3GPP [19], which details the various modes in which the UE can perform a cell change and the measurements on which such decisions are based. To this end, different cell categories are defined according to the service offered, namely acceptable, suitable, barred and reserved. For the purpose of this work, we focus on acceptable and suitable cells, given that a UE is not allowed to camp on a barred cell, and the services allowed are limited in a reserved cell (e.g., dedicated for sidelink communications). An acceptable cell is considered to be the one from which the UE can obtain a limited service, fulfilling the minimum requirements to initiate an emergency call. By contrast, a suitable cell can be defined as the one part of the selected PLMN (or an equivalent PLMN list) and belongs to the Tracking Area (TA) of the UE. In both cases, the cell has to fulfill a selection criterion based on quality parameters that will be discussed below. However, an acceptable cell is only selected when no suitable cells match the requirements.

In 3GPP specifications a UE performs a selection from these types of cells based on `RCC IDLE` or `RCC INACTIVE` state measurements, even if the cells operate under different Radio Access Technologies (RAT). For the first time, the UE Non-Access Stratum (NAS) provides a list of PLMN identities (or equivalent) and provide it to the Access Stratum (AS), which uses this information together with the radio link measurements to search for an acceptable cell. The measurements that a UE must perform for cell selection and reselection processes are described in TS 38.133 [20].

TABLE I
UE MEASUREMENT PARAMETER RANGES AS DEFINED IN [21].

Parameter	Lower Bound	Upper Bound
RSRP (NR)	-156	-31
RSRQ (NR)	-40	20
RSRP (LTE)	-140	-44
RSRQ (LTE)	-19.5	-3
Hysteresis	0	15
Offset	-24	24

This work builds on the procedure for cell selection defined by 3GPPP for intra and inter-frequency events. 3GPP TS 38.331 [21] defines 6 types of events to trigger measurements reports, and therefore a possible cell reselection process, for intra RAT cells (A1-A6 events) and 2 types for inter RAT cases (B1, B2 events). These events differ in their corresponding triggers (e.g., A2 defines the scenario when a serving cell becomes worse than a certain power threshold). Here, we do not distinguish between specific events types, and assume that when the measurement report is performed by a UE, the algorithm for cell reselection is executed. Table I shows the value ranges of the main parameters of these measurements. Note also that a UE does not consider cells with RSRP values below -110dB as suitable.

Algorithm 1 shows the procedure proposed for cell reselection. It takes into consideration not only RSRP values but also the expected resources for the UE in both the serving and the neighboring cells. The *Cell Reselection* function loops over the list of suitable cells, N, and compares the power of each with the one annotated as the best cell, c, in a ranking determined by the cell's RX level (RSRP), P. At the beginning, c is considered to be the current serving cell, S. The cell-ranking criterion for the serving cell is given by $P[c] + P_{hyst}$, while for the neighboring cells it is given by $P[i] - P_{off}$. P_{hyst} represents the hysteresis value added to the serving cell to give it a priority and avoid ping-pong. Conversely, P_{off} represents the offset of the cell. These two values are selected by the telecom operator in the range shown in Table I. If a cell with a greater power is found, then this cell i becomes the selected cell, c. If they are equal, the cell with the highest RSRQ, Q, is chosen as c, only if these measurements are maintained for more than 1 second.

Unlike from the specification, in this algorithm we add a second function, named *Bw-Q Estimate*, that weights the RX level from the cell with the resources expected to be allocated after the reselection. This function is executed when, despite finding a cell i with a lower power value, the difference is smaller than a certain penalty, p, expressed in dB, which can be accepted if the neighboring cell's resource expectations are higher. In this work, p has been chosen as double the hysteresis, P_{hyst} since otherwise the cell would not even be compared with the serving cell. More specifically, the *Bw-Q Estimate* function weights the power from the cells, P, with the ratio between configured PRBs, B, and utilized PRBs, O, and adds a penalization per number of users, U, proportional to the resources in use in the cell. Consequently, it allows the evaluation of how loaded the cell is and the proportion of resources the UE may be assigned in the future. Note that if the cell has no users connected to it or no PRBs are being used, then that cell obtains the highest ratio. Finally, if neither the serving nor the neighboring cells satisfy the minimum TX power, P_{min}, then any accepted cell providing the minimum requirement is chosen.

V. Implementation and Evaluation

A. Implementation details

Roadrunner has been implemented on top of 5G-EmPOWER [4], an SD-RAN controller designed following the CUPS principles dictated by the O-RAN Alliance. The SD-RAN controller is in charge of building the global view of the network and send control and management policies to the devices (i.e., the eNBs) in the infrastructure layer. In the current implementation the following information is gathered at the SD-RAN Controller layer:

- *RSRP/RSRQ*. The carrier received signal strength indicator measures the total power received on reference signals. The RSSI measurement is taken over the full bandwidth while the RSRP is narrow–band. In the RSRQ also the number of PRBs used is also considered.
- *Traffic Matrix*. The number of packets and bytes transmitted/received by each wireless client. The absolute packets/bytes values as well as the bitrate in the last observation window are available to the applications.

srsRAN [3] has been used to implement the eNBs while Open5GS [22] has been used as the 4G core implementation. srsRAN, and in particular the eNB application, has been extended with a software agent in order to allow communication with the SD-RAN controller. This agent is responsible for the communication with the control layer via the southbound interface and for implementing the policies from the SD-RAN controller. Furthermore, it collects information about the network state, including PHY/MAC statistics, and reports it to the SD-RAN controller.

Roadrunner has been implemented as a software module in the SD-RAN controller application layer and takes advantage of the global network view exposed by the controller to implement its cell selection policies. For this purpose the SD-RAN controller defines a Python Application Programming Interface (API) that provides a set of programming abstractions to specify network directives while sheltering the application from the complexities of the underlying wireless technology.

B. Evaluation Methodology

Our evaluation methodology aims to show how *Roadrunner* can make cell selection decisions while taking into account *both* signal quality and cell bandwidth (i.e., the number of PRBs available). We target two main scenarios, namely the single UE scenario depicted in Fig. **??** and the dual UE scenario depicted in Fig. **??**. In both scenarios a single TCP stream is generated in the downlink direction (from the core network to the UE) for each active UE. In the former scenario the UE is positioned very close (≈1m) to Cell A and a bit farther from Cell B (≈3m). We remind the reader that the Ettus B210s used in our measurements have a very limited power output and that the overall coverage range is in the order of ≈5m, so a user that is 3m away from the antenna is representative for a situation where a real user is approximately in middle zone of a real-world cell. Finally, the eNBs also have heterogeneous configurations in terms of available bandwidth,

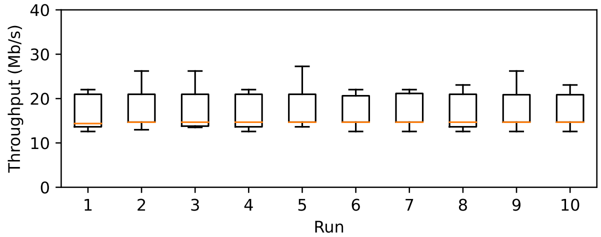
Algorithm 1 Bandwidth-aware Cell Selection Approach

Input:
S: serving cell
N: list of suitable neighboring cells that are not restricted, barred or acceptable.
A: list of acceptable neighboring cells.
P: neighboring cell's RX level value.
Q: list of cells' quality values.
P_{min}: min. required RX level in cell.
B: configured PRBs in cells.
O_n: % of PRBs used in cells.
U_n: nb. UE attached in cells.
Q_{Hyst}: hysteresis value of serving cell.
Q_{Off}: power offset of neighboring cells.
p: accepted penalty (dB)

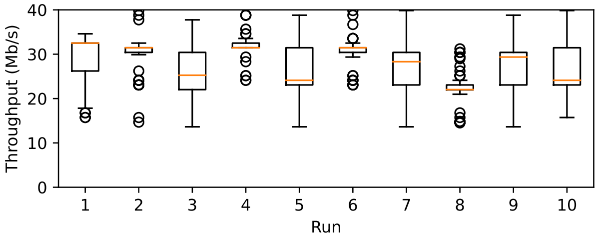
Output:
c: cell selected

function Cell Reselection
  $c \leftarrow S$ ▷ Serving cell initially set as selected
  $N.append(c)$ ▷ Append c to list of cells
  for each $i \in N_s$ **do**
    $P_d \leftarrow (P[i] - Q_{Off}) - (P[c] + Q_{Hyst})$
    if $P_d < 0$ **then**
      $c \leftarrow i$
    else if $(P_d > 0)$ **and** $(P_d < p)$ **and** $(P[i] > P_{min})$ **then** ▷ If the quality difference is below an accepted penalty, the bandwidth/power gain is calculated
      $Ratio_c \leftarrow$ Bw-Q Estimate(P, B, O, U, c)
      $Ratio_i \leftarrow$ Bw-Q Estimate(P, B, O, U, i)
      if $Ratio_i > Ratio_c$ **then**
        $c \leftarrow i$
    else
      if $P_d == 0$ **then**
        $c \leftarrow argmax(Q[i], Q[c])$
  if $c == S$ **and** $P[c] < P_{min}$ **then** ▷ If the minimum accepted power by the UE is not reached
    $c \leftarrow$ any$(A,\ P[i] > P_{min})$ ▷ Any accepted cell with the minimum power is taken
  return c

function Bw-Q Estimate(P, B, O, U, i)
  ▷ The RSRP is weighted with the radio resources expected in the cell
  if $U[i] == 0$ **or** $O[i] == 0$ **then**
    return $abs(P[i])$
  else
    return $abs(P[i] \cdot \frac{B[i] - O[i]}{O[i]} \cdot \frac{1}{U[i]})$

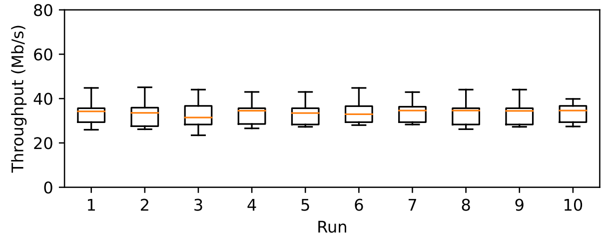


(a) Scenario 1/Legacy

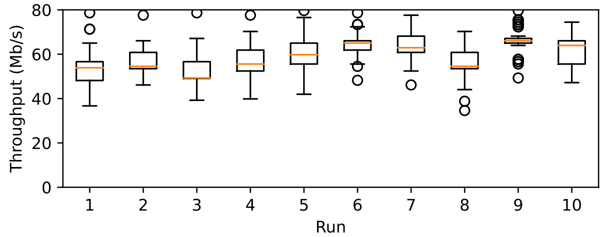


(b) Scenario 1/Optimal

Fig. 4. Aggregated network throughput for scenario 1 across 10 runs.



(a) Scenario 2/Legacy



(b) Scenario 2/Optimal

Fig. 5. Aggregated network throughput for scenario 2 across 10 runs.

i.e., Cell A supports 25 PRBs while Cell B supports 50 PRBs. In the latter scenario both UEs are placed in the same position w.r.t. the eNB and thus experience the same channel conditions. Moreover, both eNBs also support 50 PRBs. Two Ettus B210 boards with two omnidirectional antennas, each with a gain of 3dB, were used in the testbed. The UEs were configured to report RSRP/RSRQ measurement every 240ms.

C. Results

In this subsection we comment on the results of the measurement campaign conducted on our small-scale testbed.

Figure 4 shows the boxplots of the aggregated downlink throughput for scenario 1 in the legacy case and with *Roadrunner* (Optimal). As can be seen, in the legacy case (Fig. 4a) the UE is handed over to Cell A as the standard 3GPP cell selection and handover algorithm tends to prefer association stability and signal quality rather than pure network performance. For this reason the UE is not handed over to Cell B even when the channel conditions are similar. Moreover, the network does not take into account the bandwidth available at the cell and so it is unable to trade signal quality for downlink speed, i.e., accept a slightly worse channel because the available bandwidth will makeup for the worse modulation and coding rate that will have to be used. Conversely, *Roadrunner* has been configured to accept a penalty of up to -3dB if this can lead to an association opportunity with a better cell. As can be seen (Fig. 4b) this results in an overall higher downlink throughput when *Roadrunner* is used. The minor drawback is that this increased throughput appears to be slightly more unstable than the one found in the legacy situation.

Figure 5 shows the boxplots of the aggregated downlink throughput for scenario 1 in the legacy case and with *Roadrunner* (Optimal). In the legacy situation (Fig. 5a) both UEs are attached to Cell A. Note how this does not have to be like this by default, as we are assuming that the network is in this configuration either because of previous network events or simply by chance. In such a case, even though the channel quality between the two UEs and both eNBs is comparable, the mobile network will not attempt to load balance the two UEs because again the 3GPP specifications give priority to association stability, i.e., as long as the signal strength is acceptable, the network will not attempt an handover. Conversely, *Roadrunner* can detect an optimization opportunity and will load balance the two UEs across the two eNBs. This in time will result in an aggregated network throughput that is significantly higher, as can be seen in Fig. 5b.

VI. Conclusions

In this paper we have presented *Roadrunner*, a novel bandwidth-based cell-selection technology for beyond 5G networks. The proposed solution leverages an O-RAN architecture in order to go beyond pure RSRQ/RSRQ-based handover strategies. The prototype has been implemented using the 5G-EmPOWER platform [4] and srsRAN [3]. The source code has been released under a permissive license.

The performance of *Roadrunner* has been evaluated on a real-world testbed configured for different scenarios, considering homogeneous and heterogeneous channel quality distributions for the end-users. The results show that *Roadrunner* can almost double the median throughput in certain traffic scenarios while also achieving better network fairness.

Acknowledgments

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