A Novel Approach for Combined Joint Call Admission Control and Dynamic Bandwidth Adaptation in Heterogeneous Wireless Networks

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Introduction

Joint Call Admission Control and Bandwidth Adaptation

Evaluation of the Concept

Conclusion and Outlook
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Conclusion and Outlook

Common Radio Resource Management

- Mobile Network Operators (MNOs) usually operate more than one access network in the same service area
- Proper allocation and coordination of the mobile services among the different access network technologies: Common Radio Resource Management (CRRM)
- Functions are split among two types of entities:
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Two main *semi persistent* CRRM concepts:

**Joint Call Admission Control (JCAC)**
- Makes it possible to decide to which RAN the terminal or service should be deployed or handover performed to

**Dynamic Bandwidth Adaptation (DBA)**
- Keeps *blocking* and *dropping rates* on a low level
- Improves system utilization
- Based on a *generic* resource allocation approach
- Radio resources are generalized to a common basis: *Effective Bandwidth*
Scenario with two heterogeneous RANs co-deployed in the same service area
- Cells that cover the same service area are merged to a Cell Area
- Core Network coupling approach is considered
  - All semi persistent RRM functions are performed by a central entity
  - Fast dynamic RRM functions are not considered
- UE can only be connected to one RAN at a time

Utility Concept
- Utility represents a measure of relative satisfaction w.r.t. consumption of goods and services
- In the present context: Generic measurement of the gained profit of the MNO that operates the RANs
- Represented by a Utility Function
  \[ u_{i,j} = U(a_j(b), \pi_j, \rho_i) \]
  where
  - \( a_j(b) \): Application utility function, dependent on the service
  - \( \pi_j \): Priority factor, represents priority level of the user (SLA)
  - \( \rho_i \): RAN factor, set by MNO
- In the following the utility function is defined by
  \[ u_{i,j} = a_j(b) \cdot \pi_j \cdot \rho_i \]
Different types of services:

**Elastic Services**

\[
u_{\text{elastic}}(b) = 1 - e^{-\frac{b}{b_{\text{max}}}}\]

**Non-Elastic Services**

\[
u_{\text{non-elastic}}(b) = \begin{cases} 1 & b \geq b_{\text{min}} \\ 0 & b < b_{\text{min}} \end{cases}\]
**Core Concept**

- DBA and JCAC are realized in a *nested* way
- All actions are performed per Cell-Area and are performed in a *bundled* manner, each $TTI_{semi\text{-}persistent}$

**Joint Call Admission Control**

- JCAC makes it possible to decide by which RAN a terminal should be served and the resp. service should be provided
- Different policies can be implemented
- In the present case two opposed interests are taken into consideration
  - Maximization of the MNO’s profit
  - QoS requirements of the requested services need to be taken into consideration
- Modelling Approach: JCAC problem is mapped to a *Generalized Assignment Problem (GAP)*
N items need to be placed in M bins
- Each bin $C_i$ has a maximum capacity $c_i$
- Each item has a certain defined weight $w_{i,j}$ and a corresponding profit $u_{i,j}$ dependent on the bin
- Mathematical description of the problem

$$z = \max \sum_{i=1}^{m} \sum_{j=1}^{n} u_{i,j} \cdot x_{i,j}$$

s.t. $\sum_{j=1}^{n} w_{i,j} \cdot x_{i,j} \leq c_i$ $\forall i \in M = \{1, \ldots, m\}$

$$\sum_{j=1}^{m} x_{i,j} = 1 \quad \forall j \in N = \{1, \ldots, n\}$$

$$x_{i,j} = \{0, 1\} \quad \forall i \in M, j \in N$$

**Analogy between GAP to JCAC**
- Bin – Cell of a RAN
- Item – Service to be deployed

**Solution Algorithm**
- An approximative solution algorithm is required
- A solution approach has been chosen that splits the GAP into $M$ separate assignment problems per bin
  - A lot of approximative solution algorithms exist for single assignment problems
  - In the present case: a *greedy* algorithm has been chosen
Dynamic Bandwidth Adaptation is split into two parts:

**Arrival Algorithm**

- Calculates the demand of the incoming services
- Acquires as much resources as required or possible
- In case $B_{\text{req}} = \sum \forall j b_j > B_{\text{avail}}$:
  - Already deployed elastic services are sorted according to their utility slope in an ascending order
    \[ u'_1 < u'_2 < \ldots < u'_n \]
  - Already deployed services are degraded until enough resources are available
  - leads to a minor utility loss

**Departure Algorithm**

- Remaining cell capacity is allotted to all deployed elastic services
- Services are sorted according to their utility slope in a descending order
  \[ u'_1 > u'_2 > \ldots > u'_n \]
- More resources are granted to a service until $b = b_{\text{max}}$ or cell reached its defined maximum load
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Other JCAC Approaches

In order to evaluate the proposed concept another Joint Call Admission Control algorithm has been used as a reference

Adaptive Joint Call Admission Control (AJCAC)

▶ Falowo et al. propose a JCAC scheme that aims to distribute the load of incoming services w.r.t. the load of the cells
▶ Each service is considered separately
▶ A group of co-located cells is considered as an input for the JCAC algorithm
▶ For comparison reasons, DBA algorithms remain the same
A fully co-deployed LTE and HSPA environment is considered
Simulation area consists of 36 cells per RAN, with a wrap-around model
Number of users is defined by an initial number of users per cell
Each user has a randomly chosen residing time which is calculated by a range of different velocities $v_{UE} \in [0, 60] \text{ km/h}$
Event-based OMNeT++ has been used as a simulation platform
  - Extended with new modules
  - Control plane of a co-deployed UTRAN/E-UTRAN SAE system has been developed

Overall Gained Utility

$$U_{overall} = \sum_{\forall i, \forall j} u_{i,j}$$
Dropping Probability

![Dropping Probability Graph]

Blocking Probability

![Blocking Probability Graph]
Relative Cell Load

\[ \eta_i = \sum \forall j b_{i,j} \frac{B_j}{\text{capacity}} \]

Satisfied Elastic Services

\[ r_{\text{satisfied, RAN}} = \frac{N_{\text{elastic, satisfied}}}{N_{\text{elastic}}} \]
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- A novel utility definition for heterogeneous wireless networks has been defined
- Novel approach for combined JCAC and DBA has been introduced
  - Aims to improve the MNO’s revenue
  - Takes QoS requirements of the requested services into consideration
- A simulation platform has been developed in order to evaluate and compare the proposed concept
- The results show an improvement of the overall gained utility of up to 6% compared to other JCAC approaches while keeping the system performance metrics at an acceptable level
Thank you for your attention!

Questions?

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