Cognitive Management of Bandwidth Allocation Models with Case-Based Reasoning

Evidences Towards Dynamic BAM Reconfiguration

ILLUSTRATED TECHNICAL PAPER

Eliseu M. Oliveira, Rafael F. Reale and Joberto S. B. Martins

Abstract

This "**ILLUSTRATED TECHNICAL PAPER**" presents the slides of the paper "Cognitive Management of Bandwidth Allocation Models with Case-based Reasoning - Evidences Towards Dynamic BAM Reconfiguration".

The talk was presented at **IEEE Symposium on Computers and Communications - ISCC 2018**, 25 - 28 June 2018 at Natal, Brazil.

The "illustrated technical paper format" format is used with slides, complementary text and bibliographic references to subsidize and enrich paper contents lecture.

Index Terms

Cognitive Management, Resource Allocation, Case-based Reasoning, Bandwidth Allocation Model, Network Management, Generalized Bandwidth AllocaTion Model, MultiProtocol Label switching, Maximum Allocation Model, AllocTC-Sharing, Russian Dolls Model, CBR, GBAM, MPLS, MAM, RDM, ATCS.

1 PAPER ABSTRACT

MAnagement is a complex task in today's heterogeneous and large scale networks like Cloud, Internet of Things (IoT) , vehicular and Multiprotocol Label Switching (MPLS) networks. Likewise, researchers and developers envision the use of artificial intelligence techniques to create cognitive and autonomic management tools that aim better assist and enhance the management process cycle. Bandwidth Allocation Models (BAMs) are a resource allocation solution for networks that need to share and optimize limited resources like bandwidth, fiber or optical slots in a flexible and dynamic way. This paper proposes and evaluates the use of Case-based Reasoning (CBR) for the cognitive management of BAM reconfiguration in MPLS networks. The results suggest that CBR learns about bandwidth request profiles associated with the current network state and is able to dynamically define or assist in BAM reconfiguration. The BAM reconfiguration approach adopted is based on switching among available BAM implementations (Maximum Allocation Model, Russian Dolls Model and AllocTC-Sharing). The cognitive management proposed allows BAMs self-configuration and results in optimizing the utilization of network resources.

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3 PAPER SLIDES

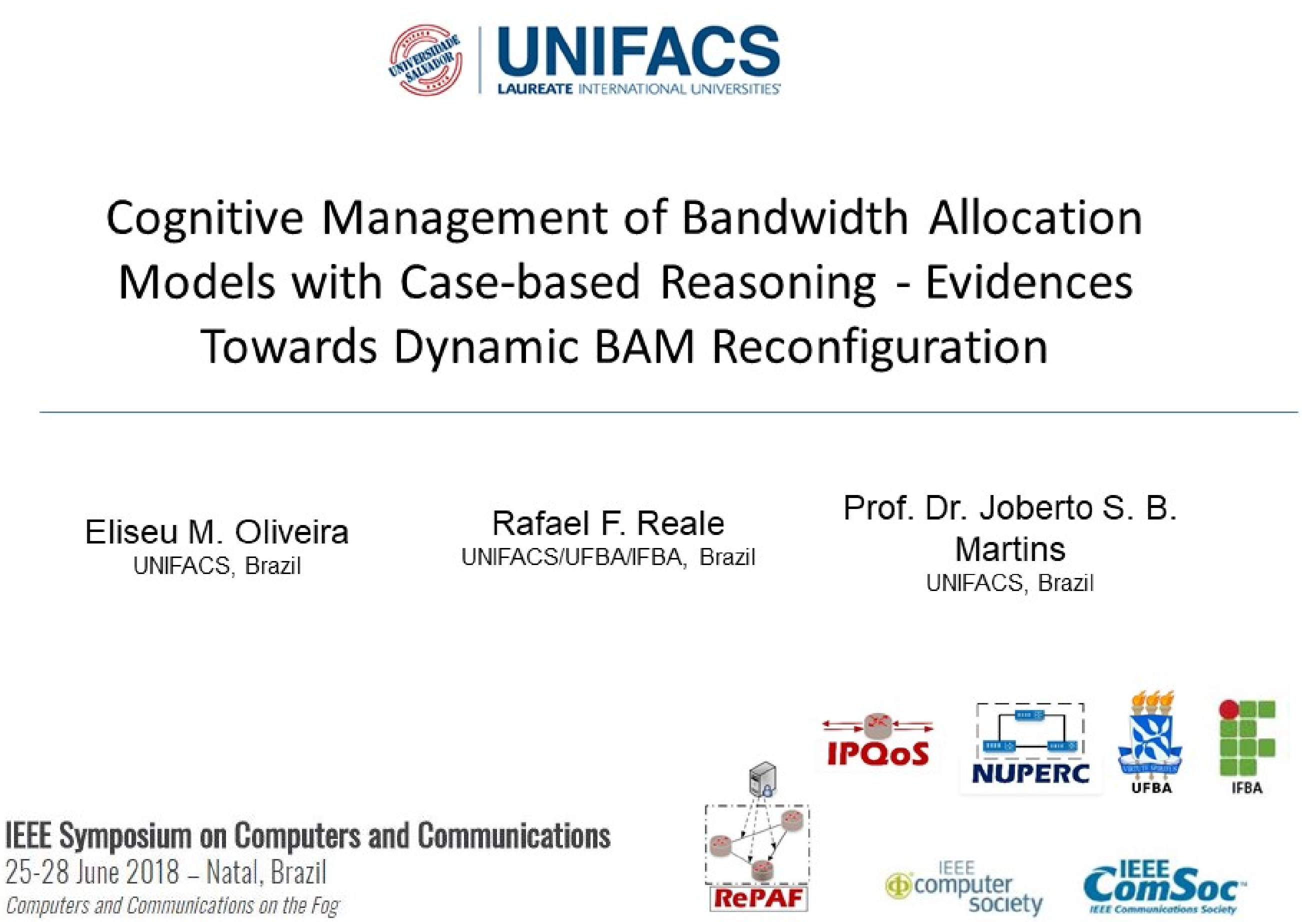

Fig. 1.

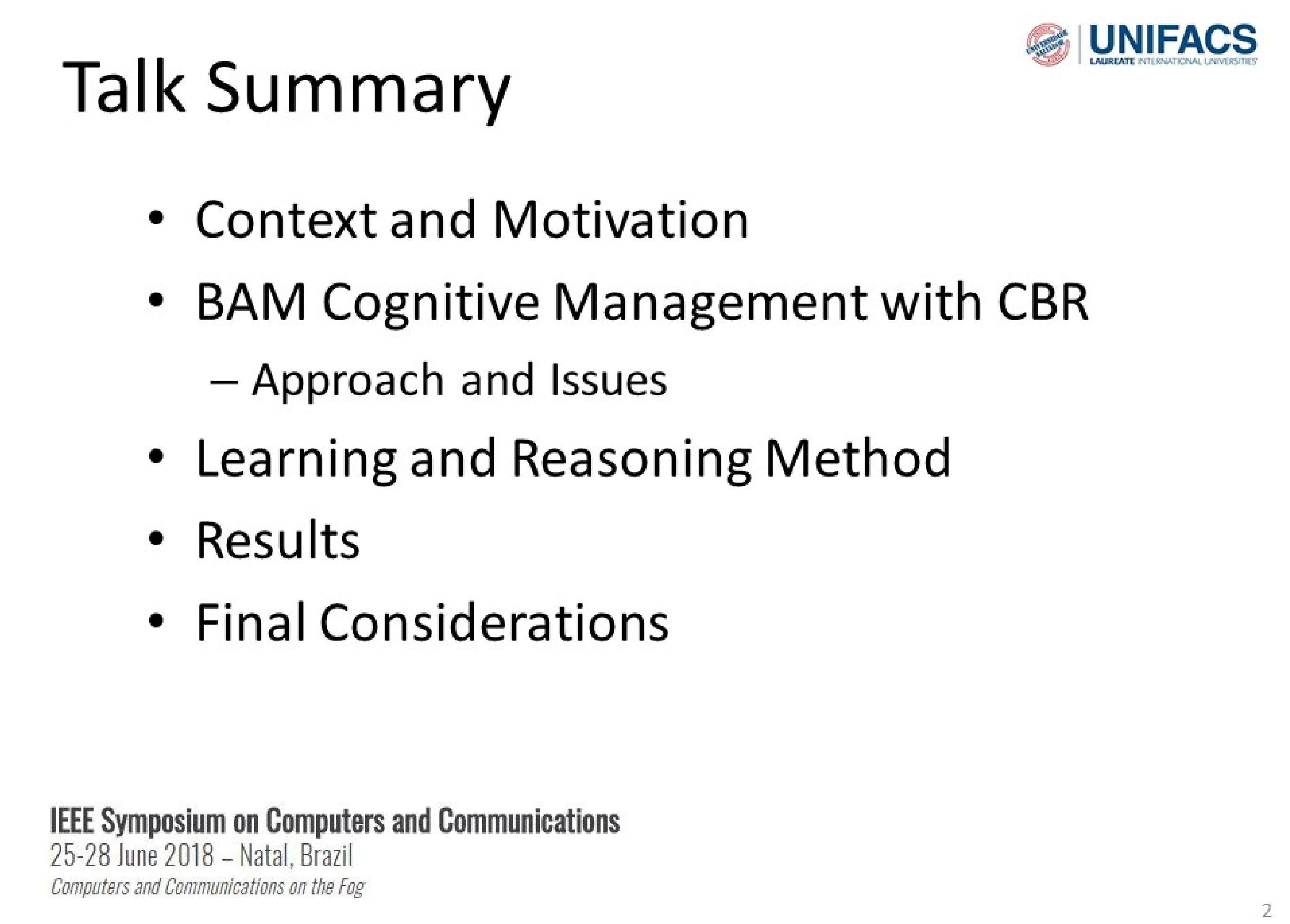

Fig. 2.

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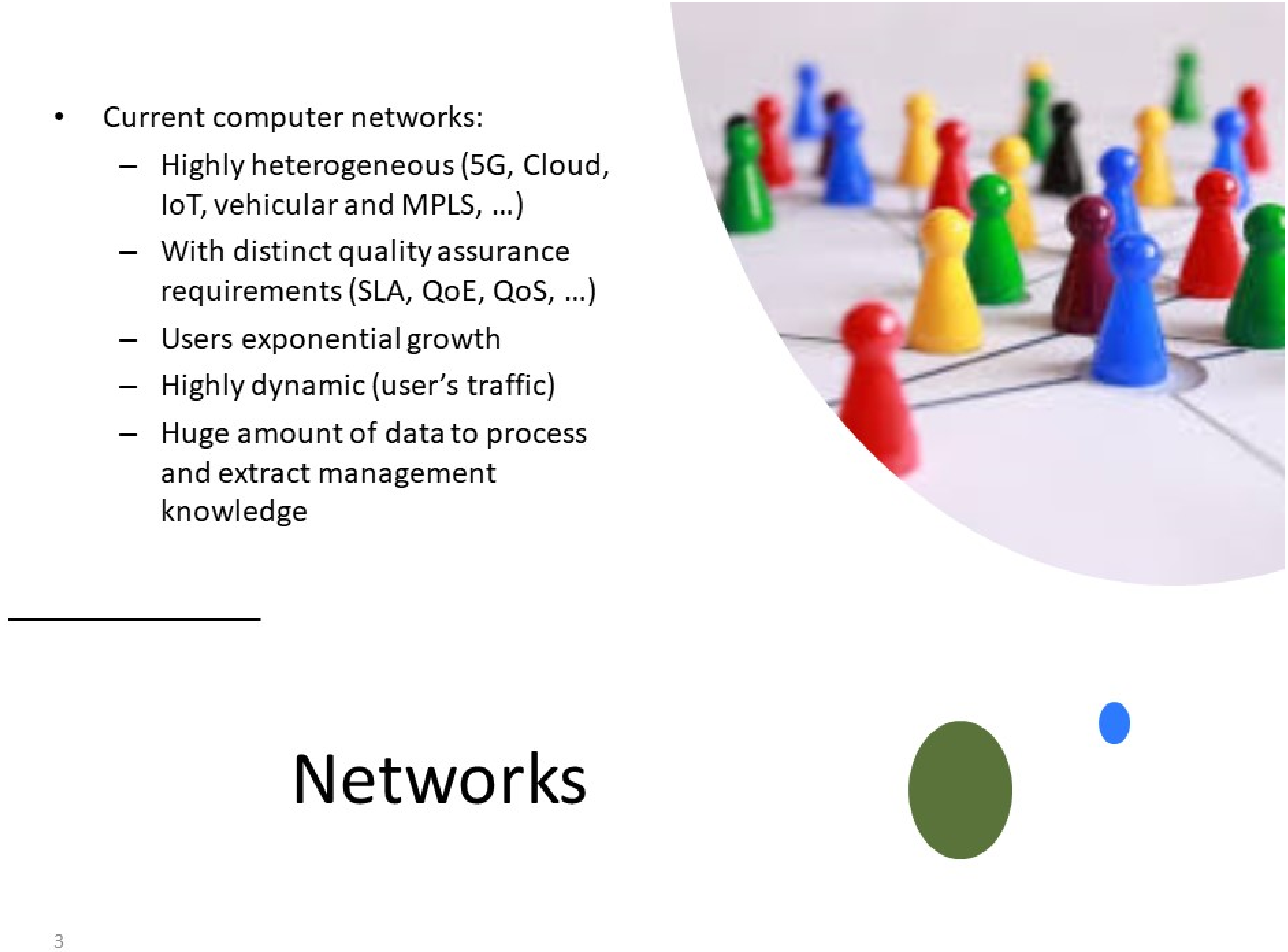

Fig. 3.

−− > **PAPER TEXT EXTRACT**:
"The current scenario of communication networks, such as 5G, Cloud, IoT, vehicular and MPLS networks, is marked by a wide variety and large distribution of services, applications and users alongside with a high volume of data exchanges with heterogeneous quality assurance requirements (Service Level Agreement - SLA, Quality of Experience - QoE, Quality of Service - QoS) [1]. These actual networks are highly heterogeneous, have to deal with an exponential growth in the number of users, have a huge amount of data to process and extract management knowledge, are highly dynamic in terms of user's demands and are subject to failure [2]".

−− > Papers to read:

−− > Complementary papers: [1] [2]

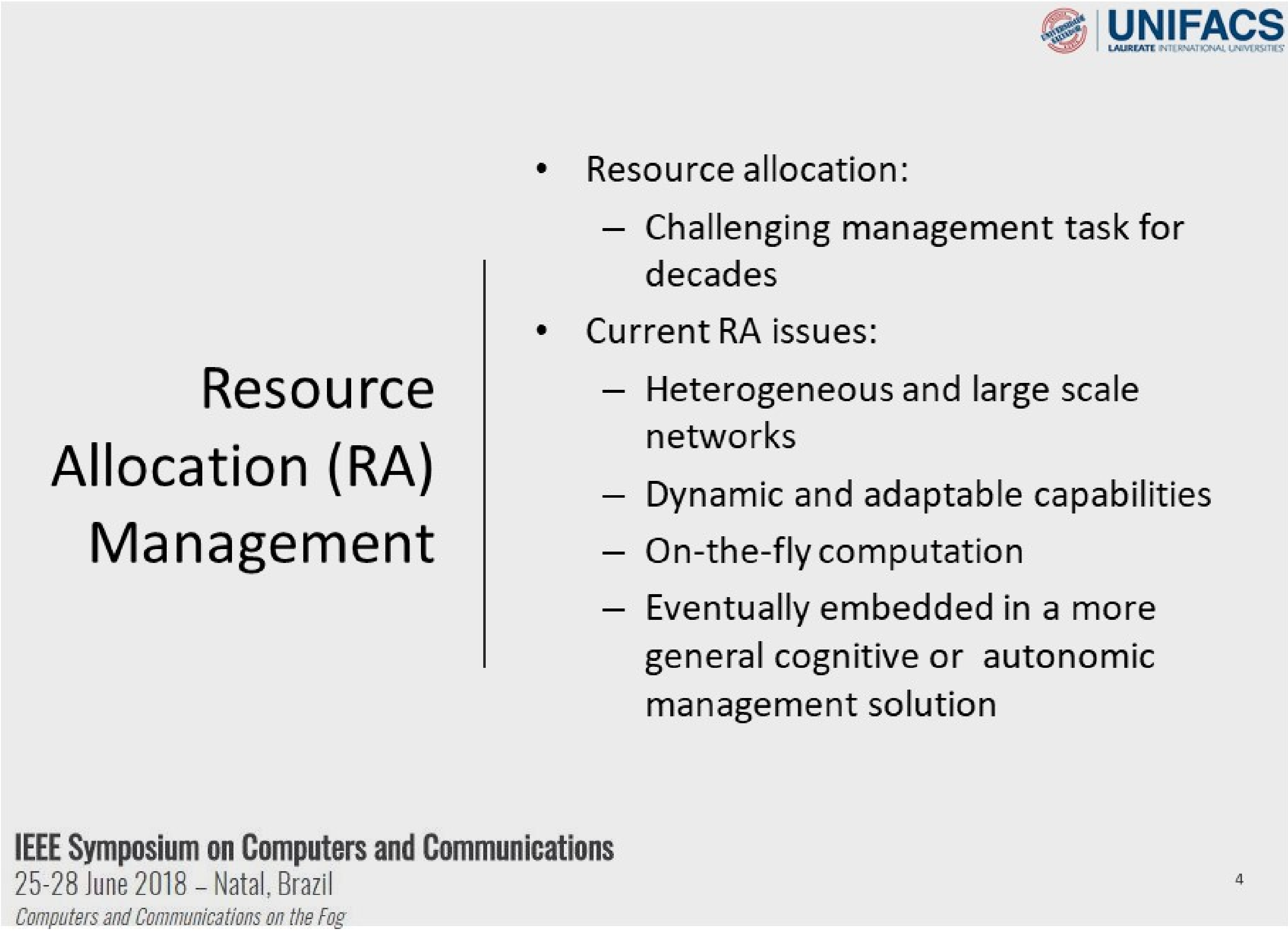

Fig. 4.

−− > **PAPER TEXT EXTRACT**:
"Resource allocation for communications has been a challenging management task for decades. Current resource allocation proposals do reflect the aforementioned communications network scenario evolution and inherent requirements. In effect, resource allocation methods, eventually embedded in a more general autonomic management solution, must support heterogeneous and large scale networks, must have dynamic and adaptable capabilities, should preferably guarantee on-the-fly computation and, eventually, are distributed [4] [5]".

−− > Papers to read: [4] [5]

−− > Complementary papers:

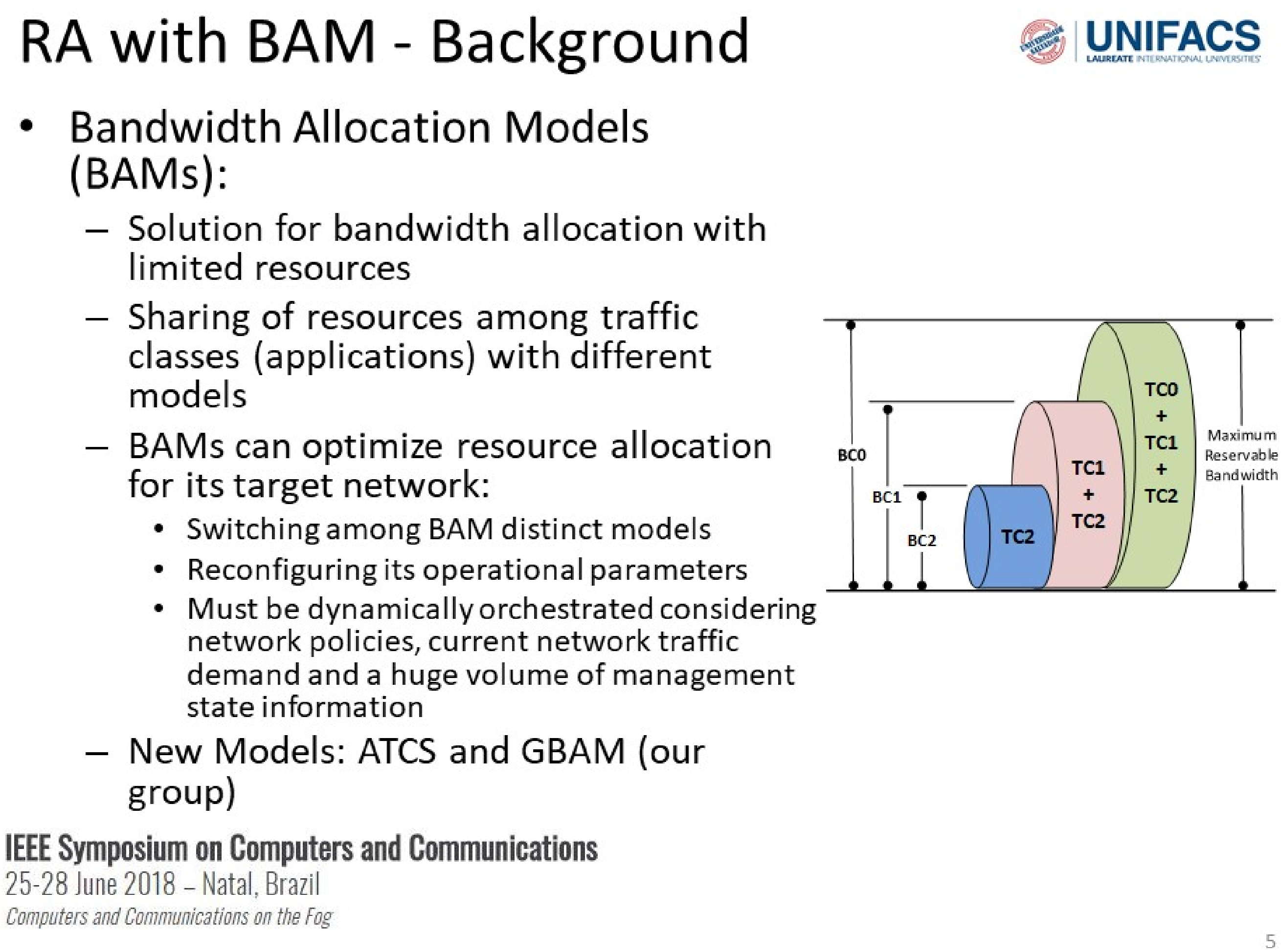

Fig. 5.

−− > **PAPER TEXT EXTRACT**:

"Bandwidth Allocation Models (BAMs) are a solution for resource allocation. BAMs allow the definition of application or traffic classes and control the distribution and sharing of resources among them [6]. BAMs can effectively optimize resource allocation for the target networks by either reconfiguring its operational parameters or switching among BAM distinct models (MAM - Maximum Allocation Model, RDM - Russian Dolls Model and ATCS - AllocTC-Sharing). BAM reconfiguration and BAM switching tasks must be dynamically orchestrated considering network policies, current network traffic demand and a huge volume of management state information [6].".

−− > Papers to read: [6]

−− > Complementary papers: [29]

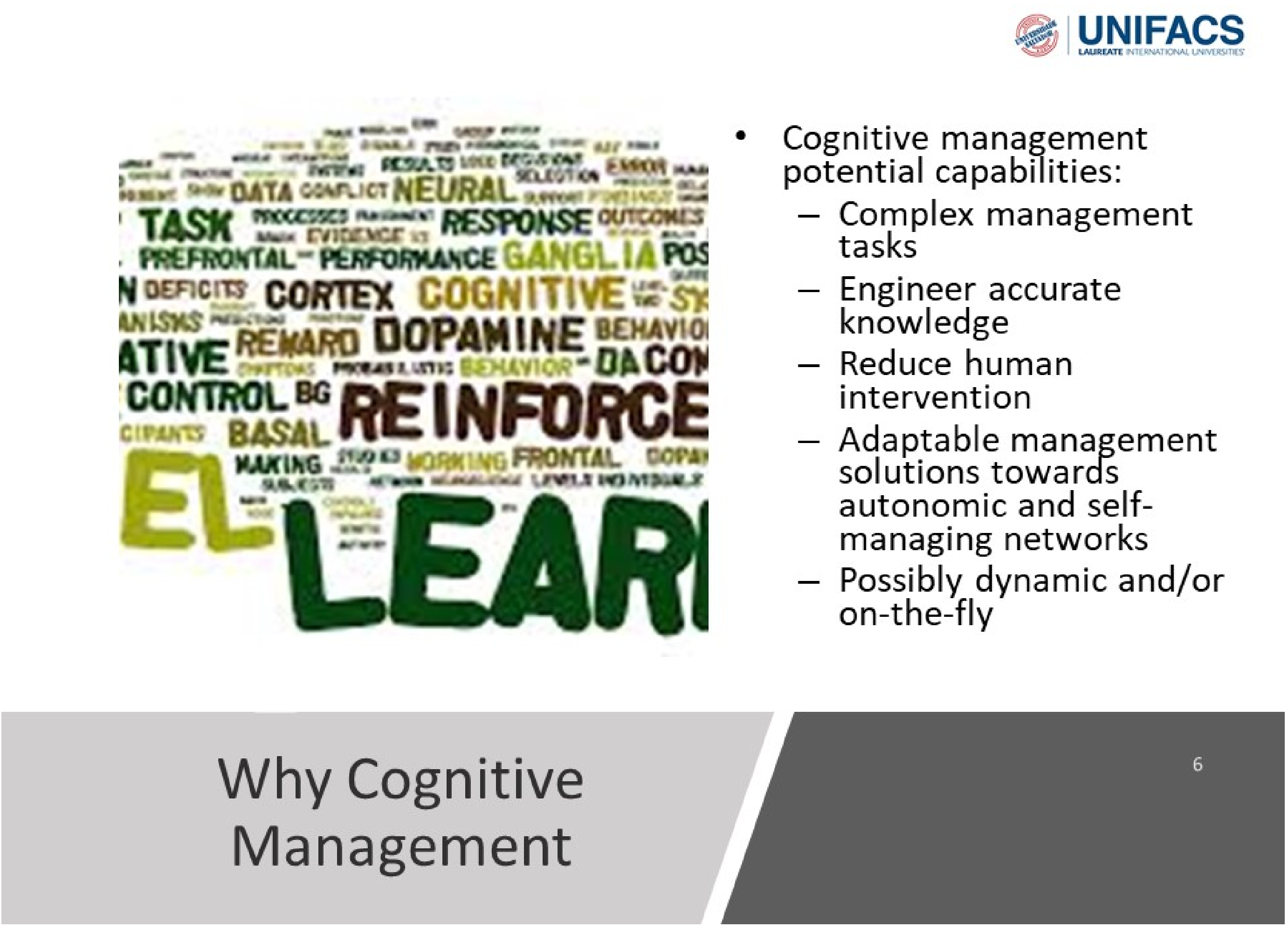

Fig. 6.

−− > **PAPER TEXT EXTRACT**:

"The motivation is to develop a CBR-based autonomic management solution for BAMs that reduces human intervention in the management process and allow the optimization of resources (bandwidth) in MPLS networks.

As discussed in [3] and [2], cognitive management using artificial intelligent techniques became more recently a relevant asset for communications management. Cognitive management has been applied using different AI techniques for cellular systems [9], vehicular networks [10], satellite communications [11], small cells mobile systems [12] and, more extensively, to cognitive radio [13]."

−− > Papers to read: [2] [3]

−− > Complementary paper: [27] [9] [10] [11] [12] [13]

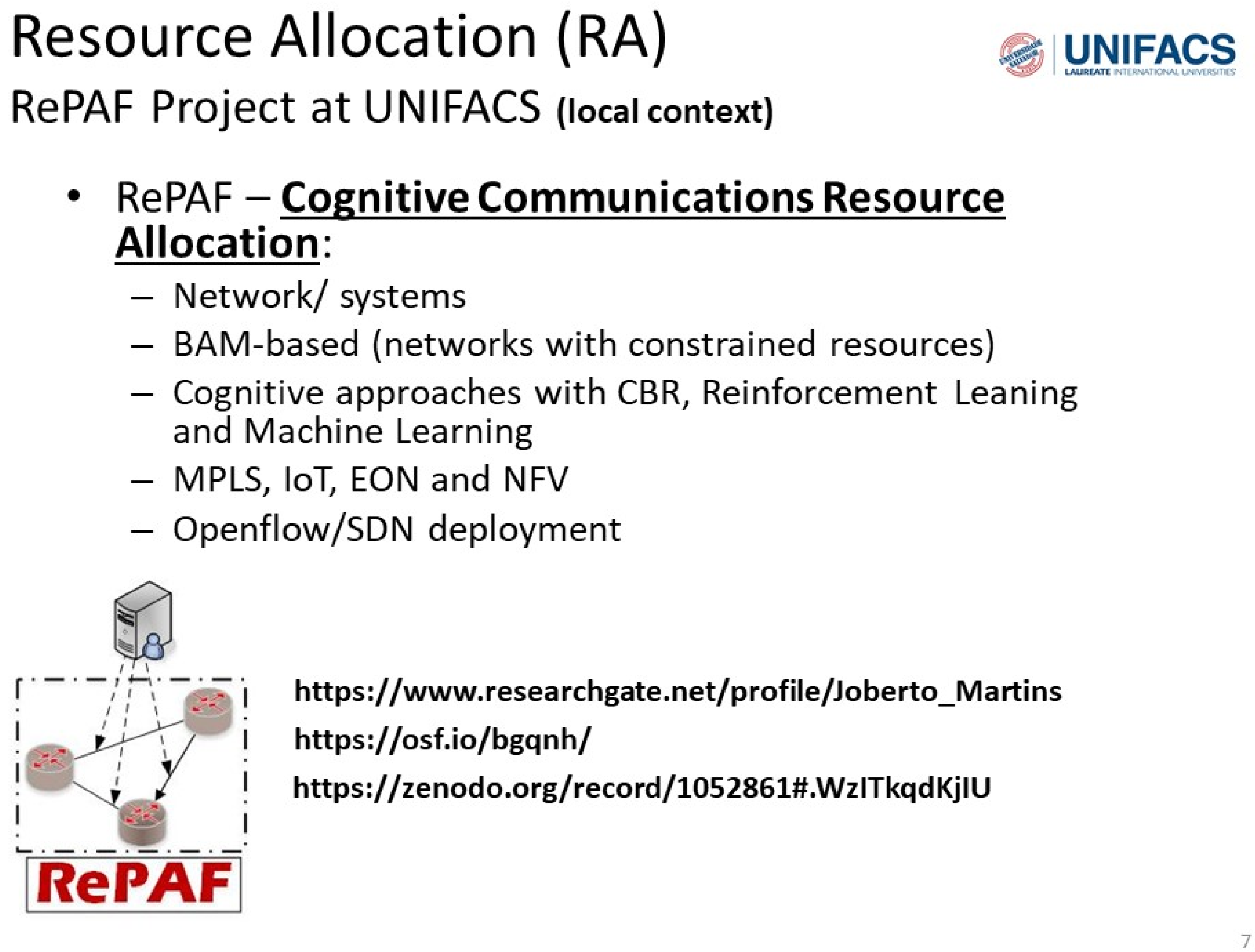

Fig. 7.

−− > Papers to read: [20]

−− > sites to visit:
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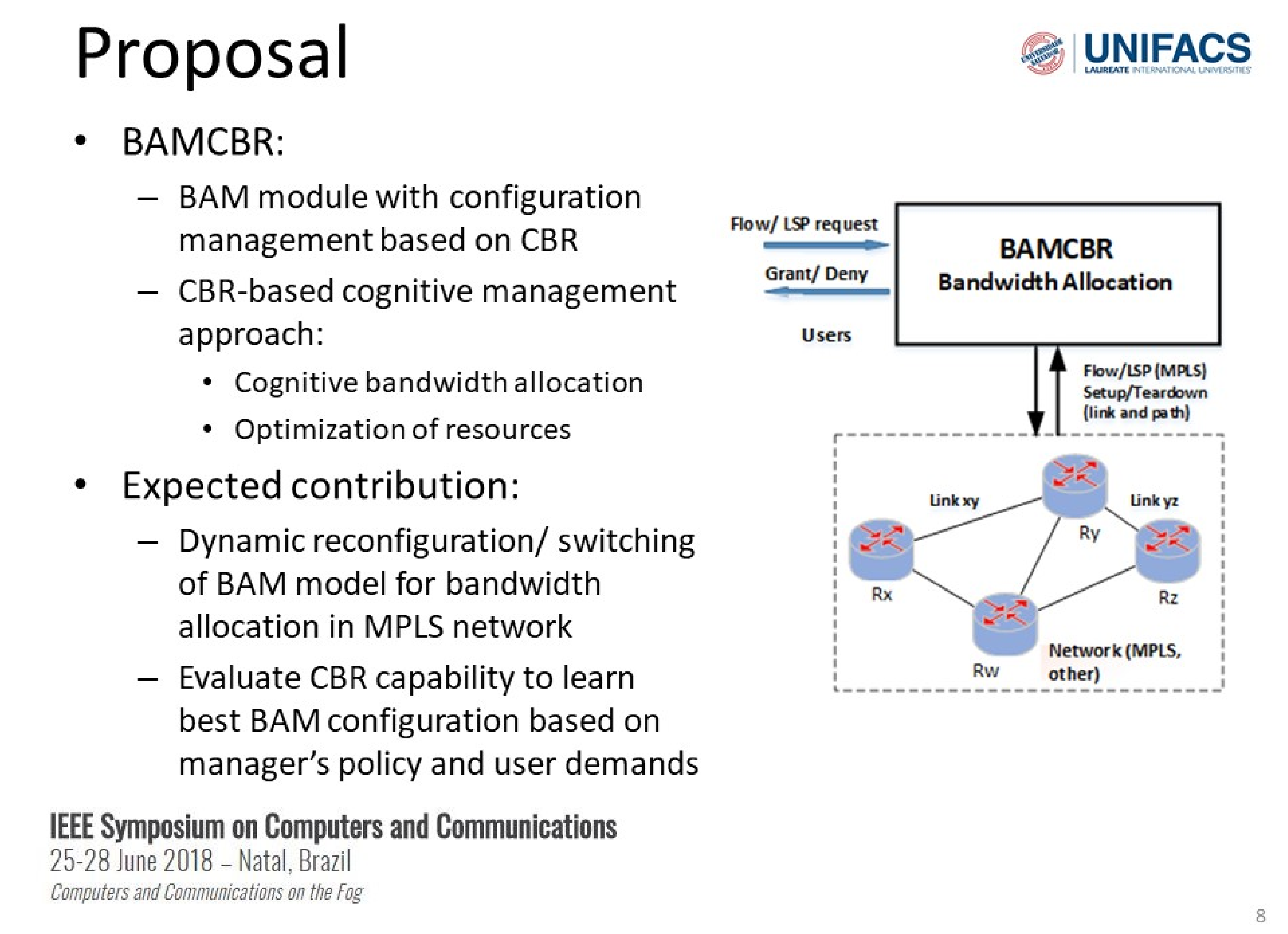


Fig. 8.

−− > **PAPER TEXT EXTRACT**:
"The proposed BAMCBR module is part of the REPAF project [20] in which BAMs and cognitive management are investigated to allocate resources for MPLS, IoT, Elastic Optical Networks and Network Function Virtualization."

−− > Papers to read: [20]

−− > Complementary papers: [30]

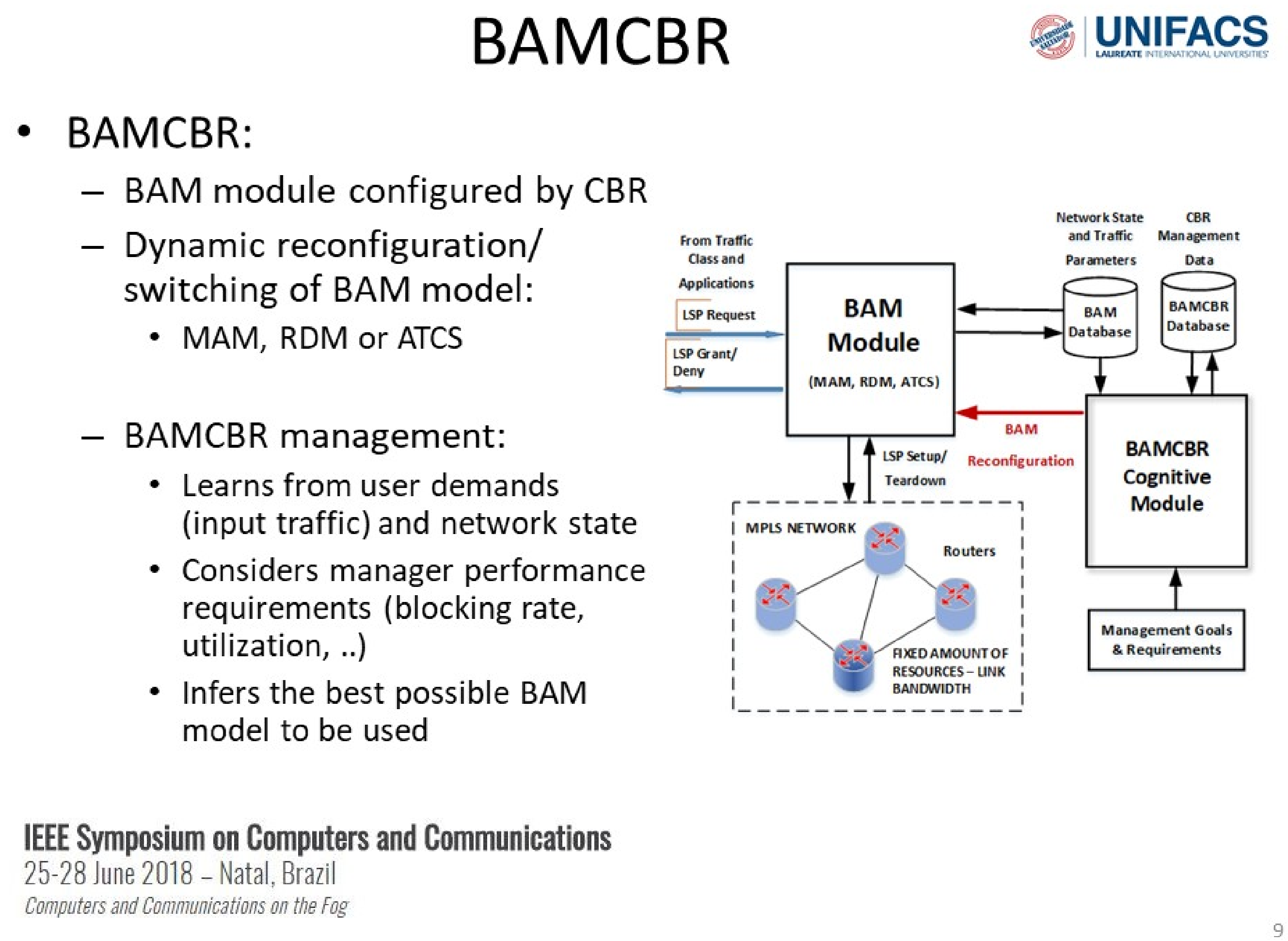


Fig. 9.

−− > **PAPER TEXT EXTRACT**:

"BAM configuration involves 3 phases:

i) the definition of classes of services (Traffic Classes - TCs) with common requirements (QoS, SLA or other user/ application parameter);

ii) the definition of the amount of bandwidth per class (Bandwidth Constraint - BC); and

iii) BAM model configuration with an inherent behavior for resource sharing among TCs. Traffic classes are typically static since they put together applications/ users with common network requirements.

Consequently, cognitive management may effective explore two configuration alternatives:

i) the amount of bandwidth defined per class; or

ii) the sharing strategy among TCs. BAMCBR proposal explores the reconfiguration of the sharing strategy."

−− > Papers to read:

−− > Complementary papers: [31] [6]

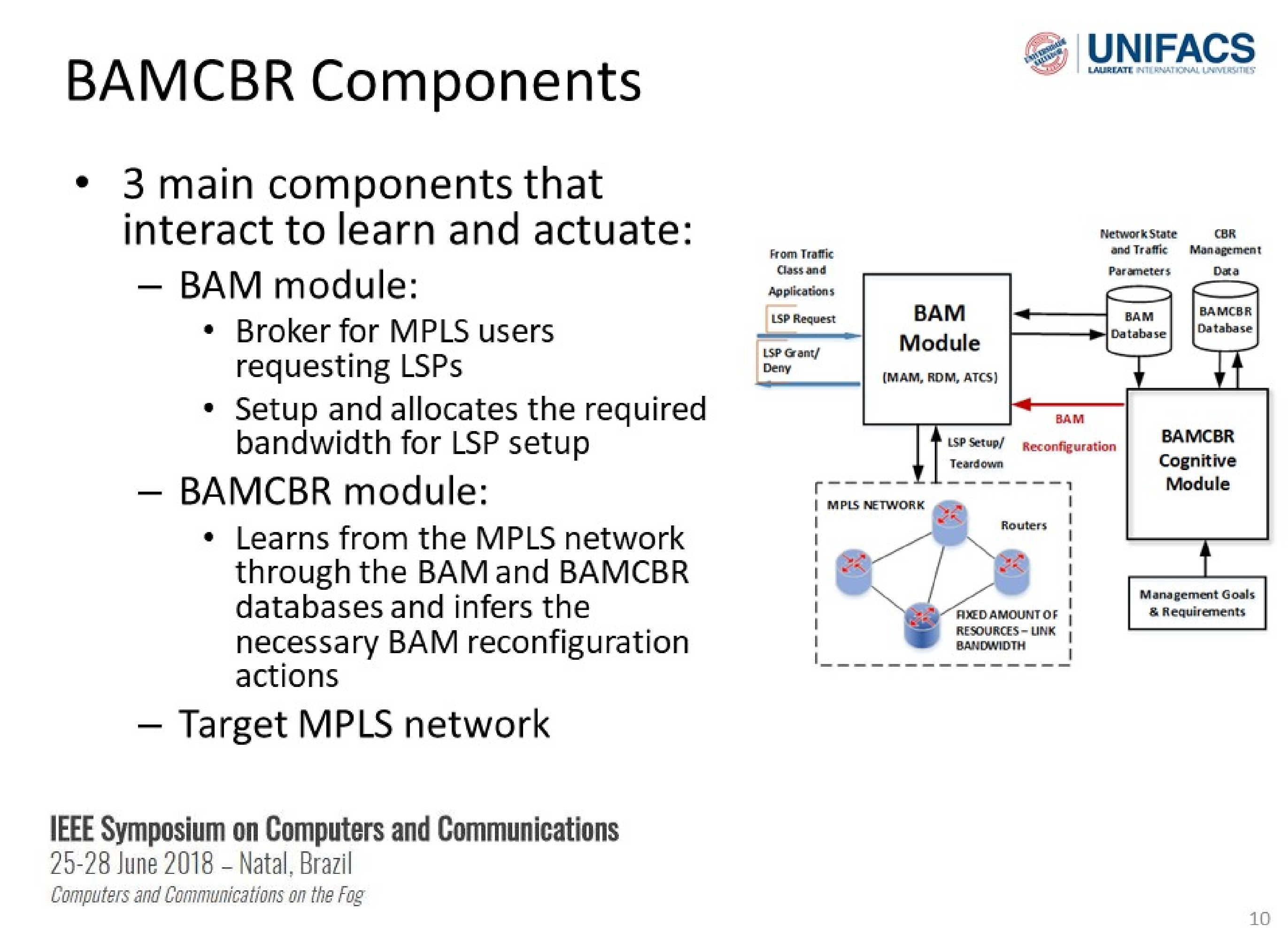


Fig. 10.

−− > **PAPER TEXT EXTRACT**:

"There are 3 components that interact to learn and actuate: the BAM module, the BAMCBR module and the target MPLS network. The BAM module acts as a broker for MPLS users requesting Label Switch Paths (LSPs) setup and allocates the required bandwidth (network links resource) for LSP setup. The BAMCBR module learns from the MPLS network through the BAM and BAMCBR databases and infers the necessary BAM reconfiguration actions."

−− > Papers to read:

−− > Complementary papers:

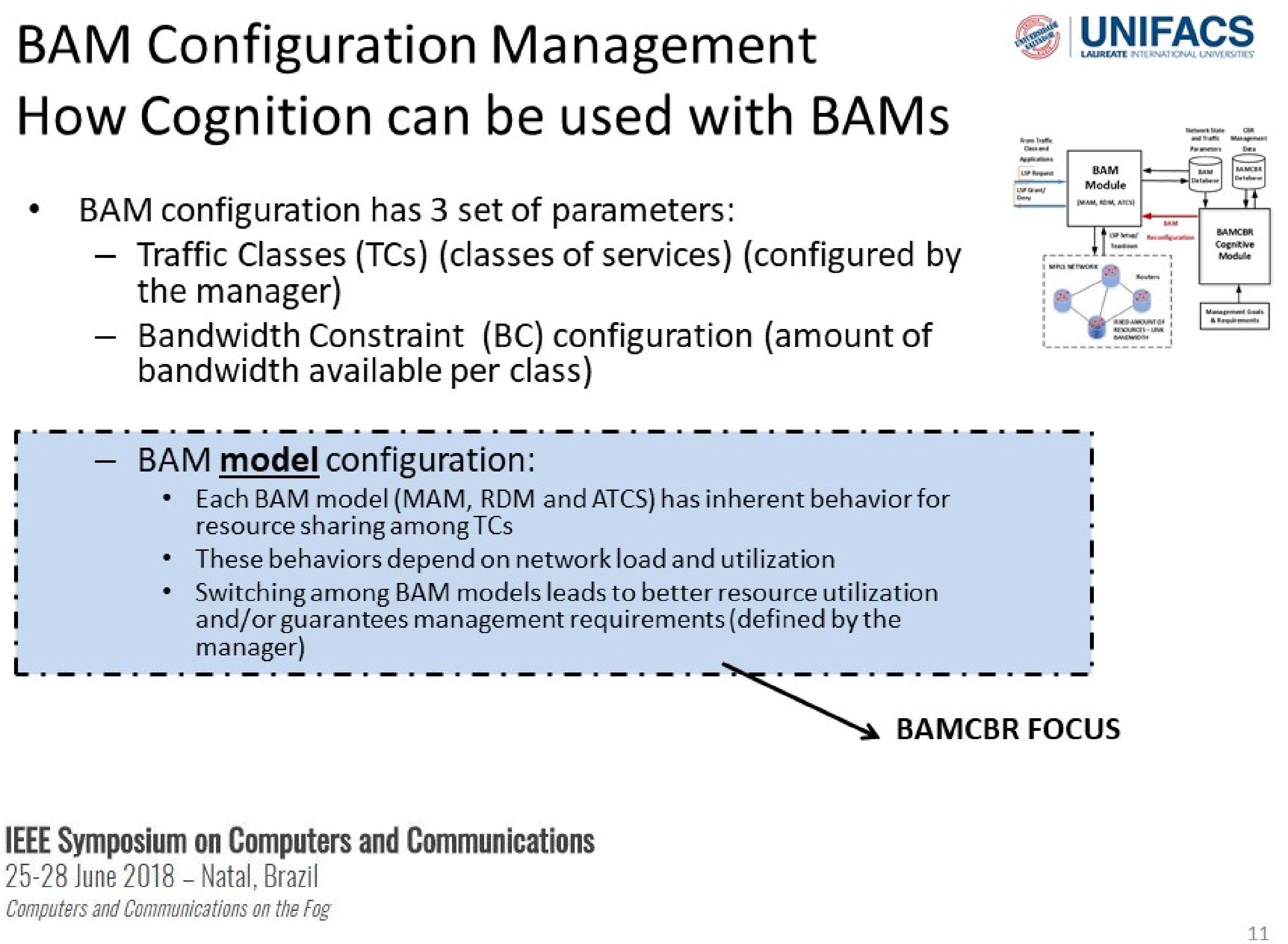
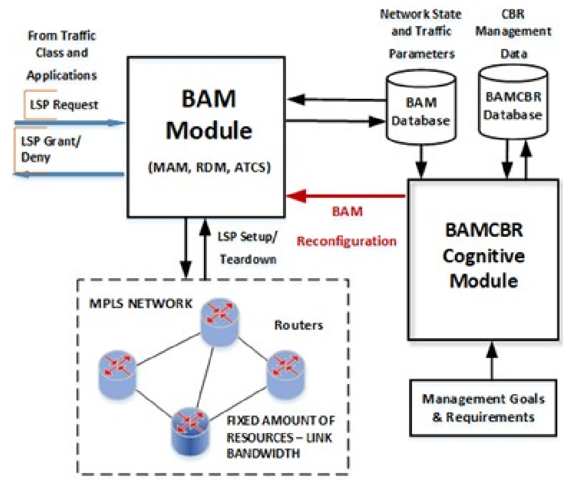


Fig. 11.

−− > Papers to read:

−− > Complementary papers: [31] [6]

BAMCBR Cognitive Reconfiguration



- With new LSP requests:
  - Changing BAM model changes TC sharing
  - Dynamic option for BAM is the cognitive management action pursued

Traffic Class Sharing	MAM	RDM	ATCS
“High-to-Low” (HTL)	*No*	*Yes*	*Yes*
“Low-to-High” (LTH)	*No*	*No*	*Yes*
TCs isolation	*High*	*Low*	*Low*

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Fig. 12.

−− > Papers to read:
−− > Complementary papers:

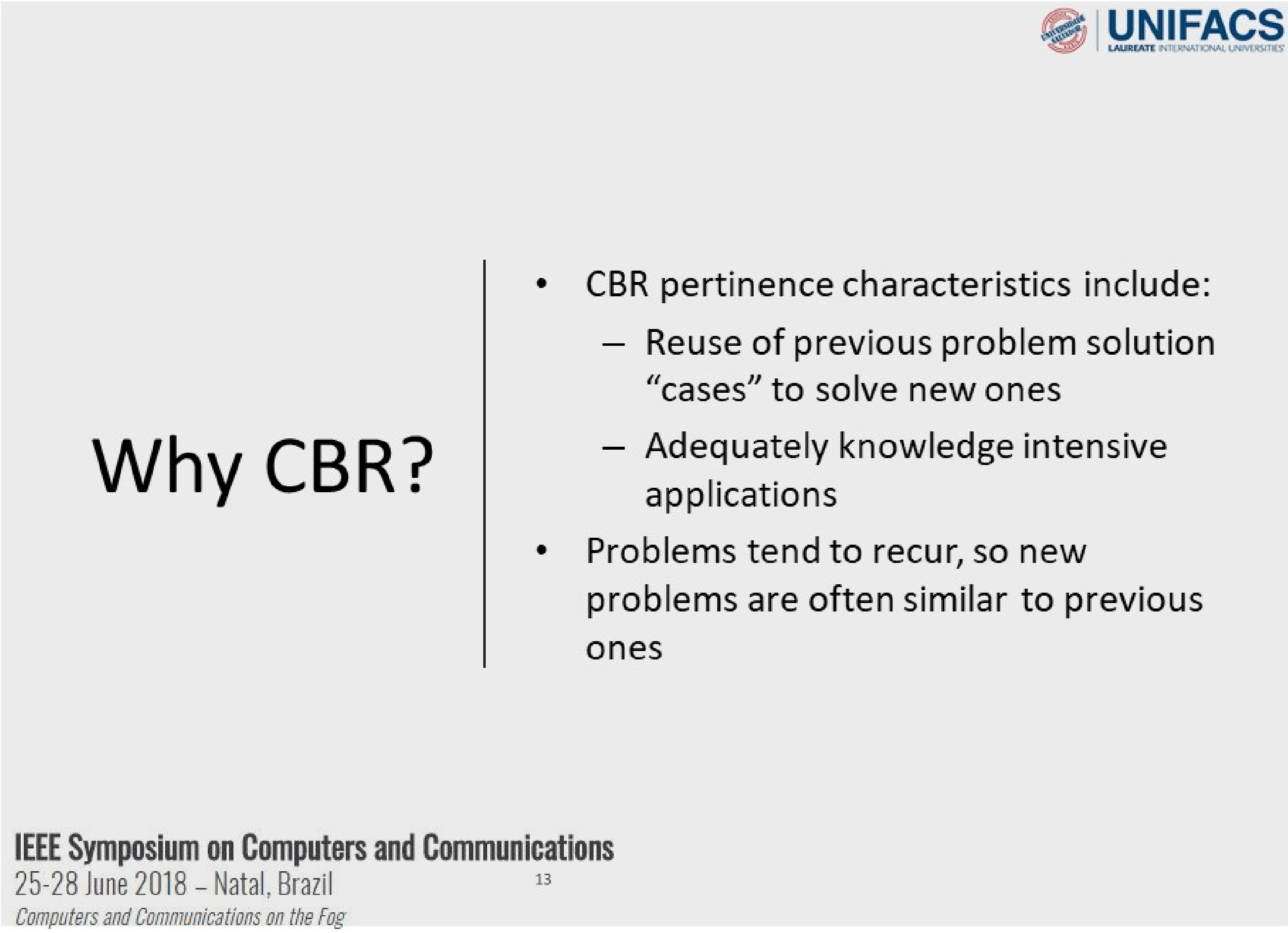

Fig. 13.

−− > **PAPER TEXT EXTRACT**: "The most relevant CBR pertinence characteristics include:
i) the fact that CBR is based on the reuse of previous problem solution “cases” to solve new ones; and
ii) CBR supports adequately knowledge intensive applications. By intuition, is common sense that problems tend to recur, so new problems are often similar to previous ones."

−− > Papers to read: [24] [25]

−− > Complementary papers: [22]

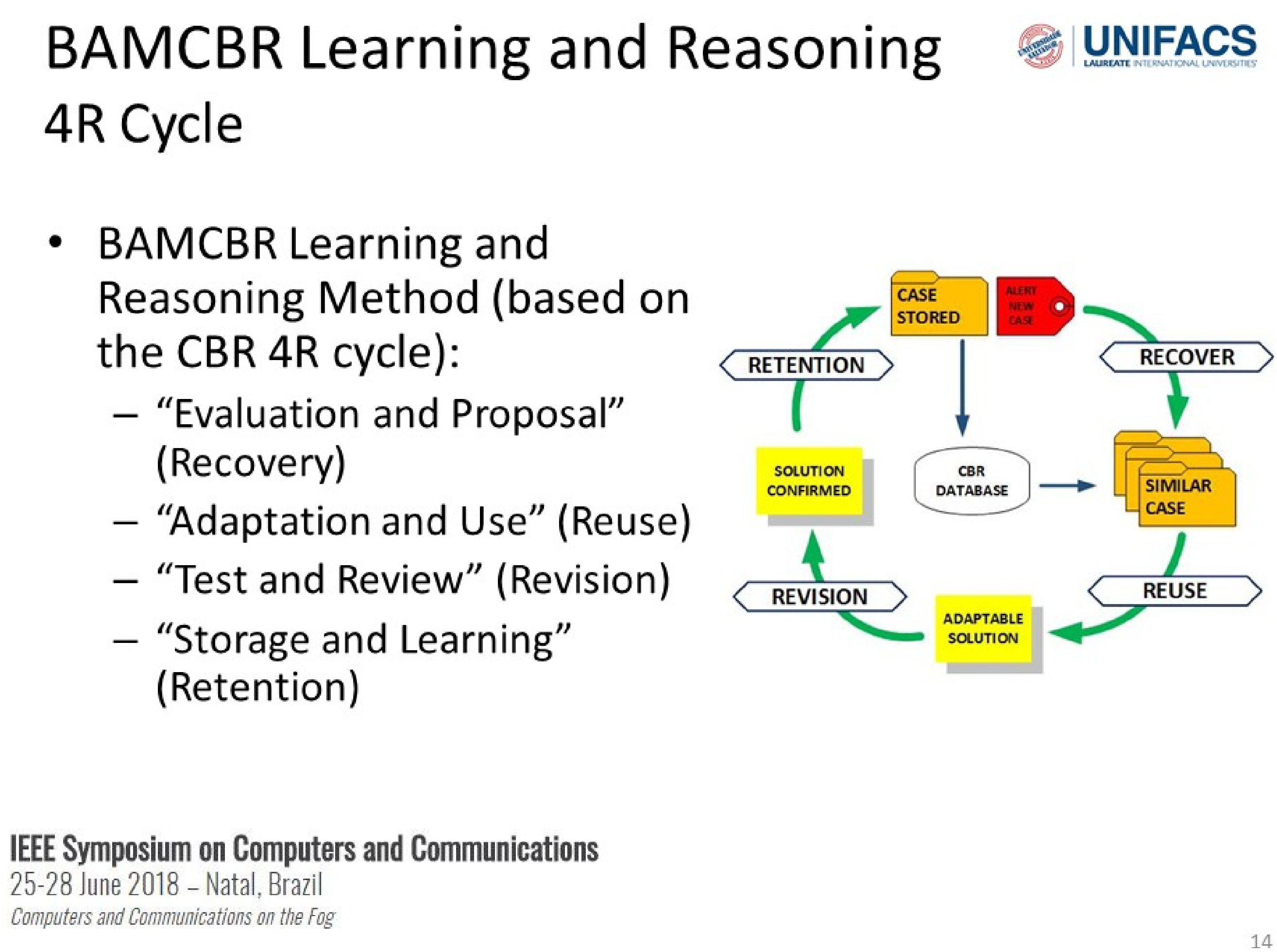

Fig. 14.

−− > **PAPER TEXT EXTRACT**:

"The BAMCBR module is based on the CBR 4R cycle defined by [26] that encompasses a cycle of continuous reasoning composed of four main stages:

i) "Evaluation and Proposal" (Recovery) - Responsible for interpreting the data obtained and searching the knowledge base for the best alternative (configuration) for the current state of the network.

ii) "Adaptation and Use" (Reuse) - Responsible for adapting the proposed solution and applying it to the network.

iii) "Test and Review" (Revision) - Responsible for verifying the effectiveness of the solution applied and proposing changes, if necessary.

iv) "Storage and Learning" (Retention) - Responsible for assimilating acquired knowledge in the process of analysis and planning for faster execution in future occurrence."

−− > Papers to read: [26]

−− > Complementary papers:

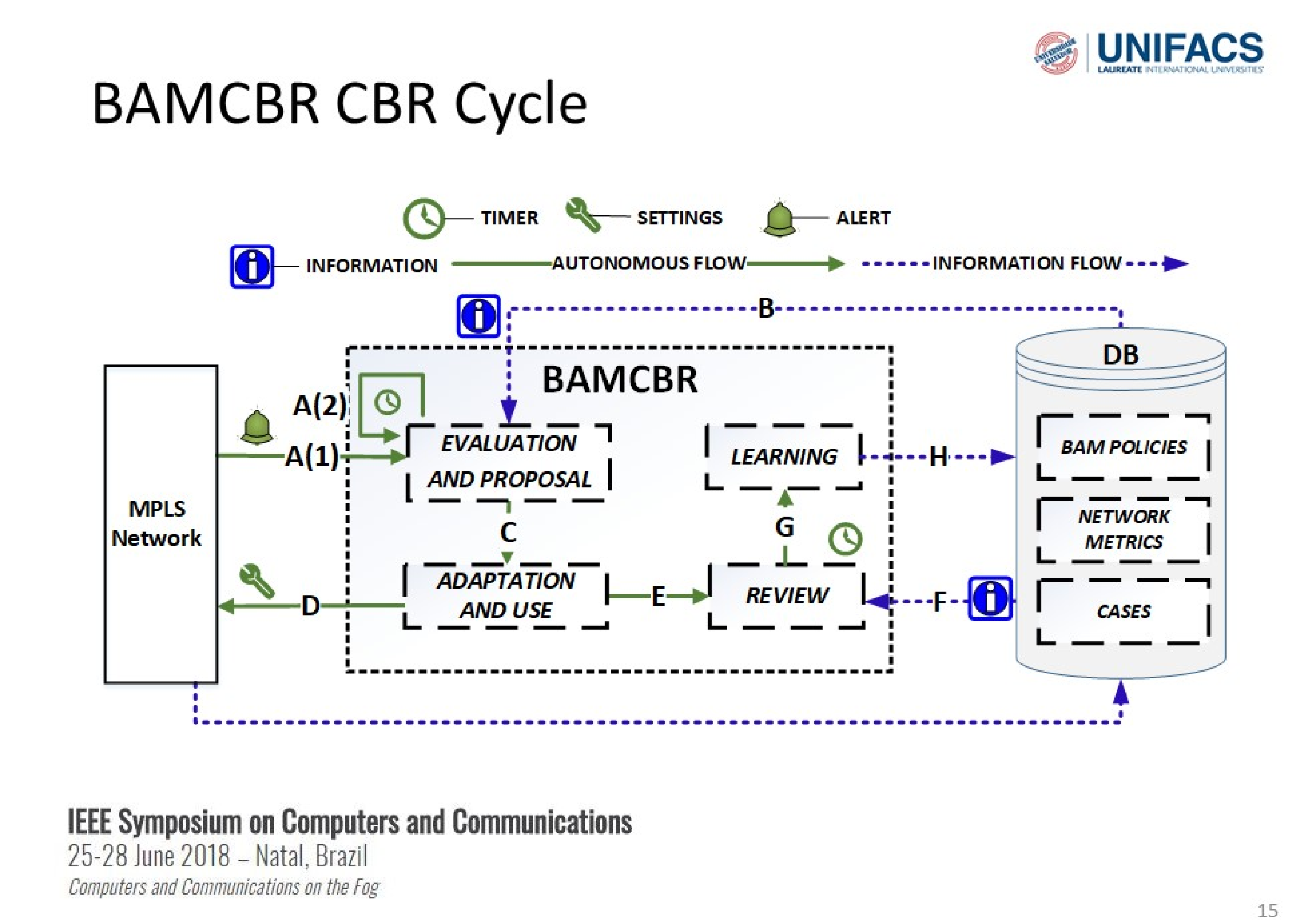

Fig. 15.

−− > **PAPER TEXT EXTRACT**: "The BAMCBR cycle starts with the “Evaluation and Proposal” stage. This task can be activated in two different ways:
i) reactively; or
ii) proactively.
Reactive Mode (A1) - Occurs when an external entity requests an analysis and solution for the current network state, with the purpose of obtaining an improvement and/or optimization of this one.
Proactive Mode (A2) - Occurs from time to time according to the internal timer setting, to proactively check network state and, if necessary, to propose improvement actions."

−− > Papers to read:

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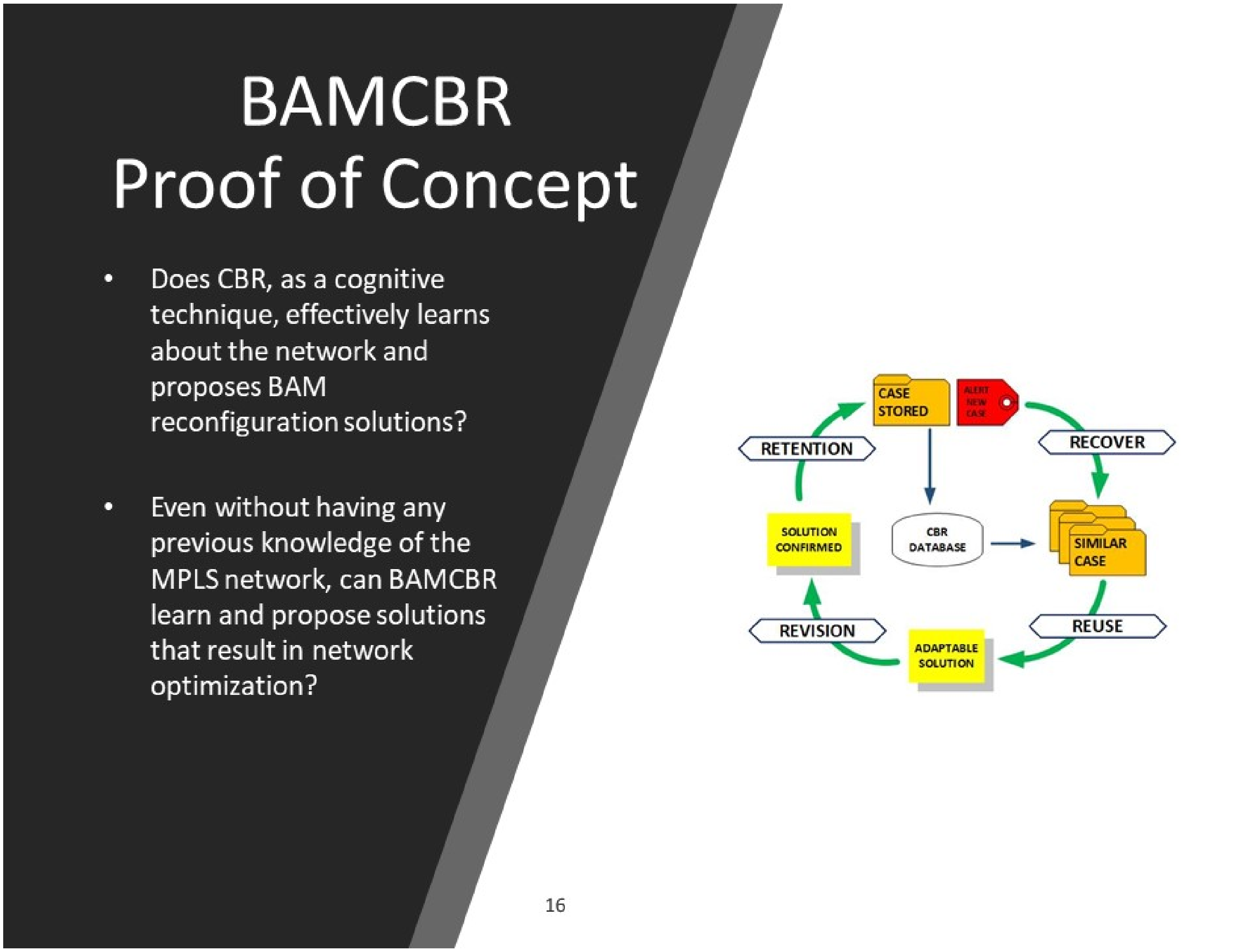


Fig. 16.

−− > **PAPER TEXT EXTRACT**:
"A proof of concept was carried out with BAMCBR module to verify the following capabilities:
ii) Does CBR, as a cognitive technique, effectively learns about the MPLS network and proposes reconfiguration solutions?
ii) Even without having any previous knowledge of the MPLS network, can BAMCBR learn and propose solutions that result in network optimization?"

−− > Papers to read:

−− > Complementary papers:

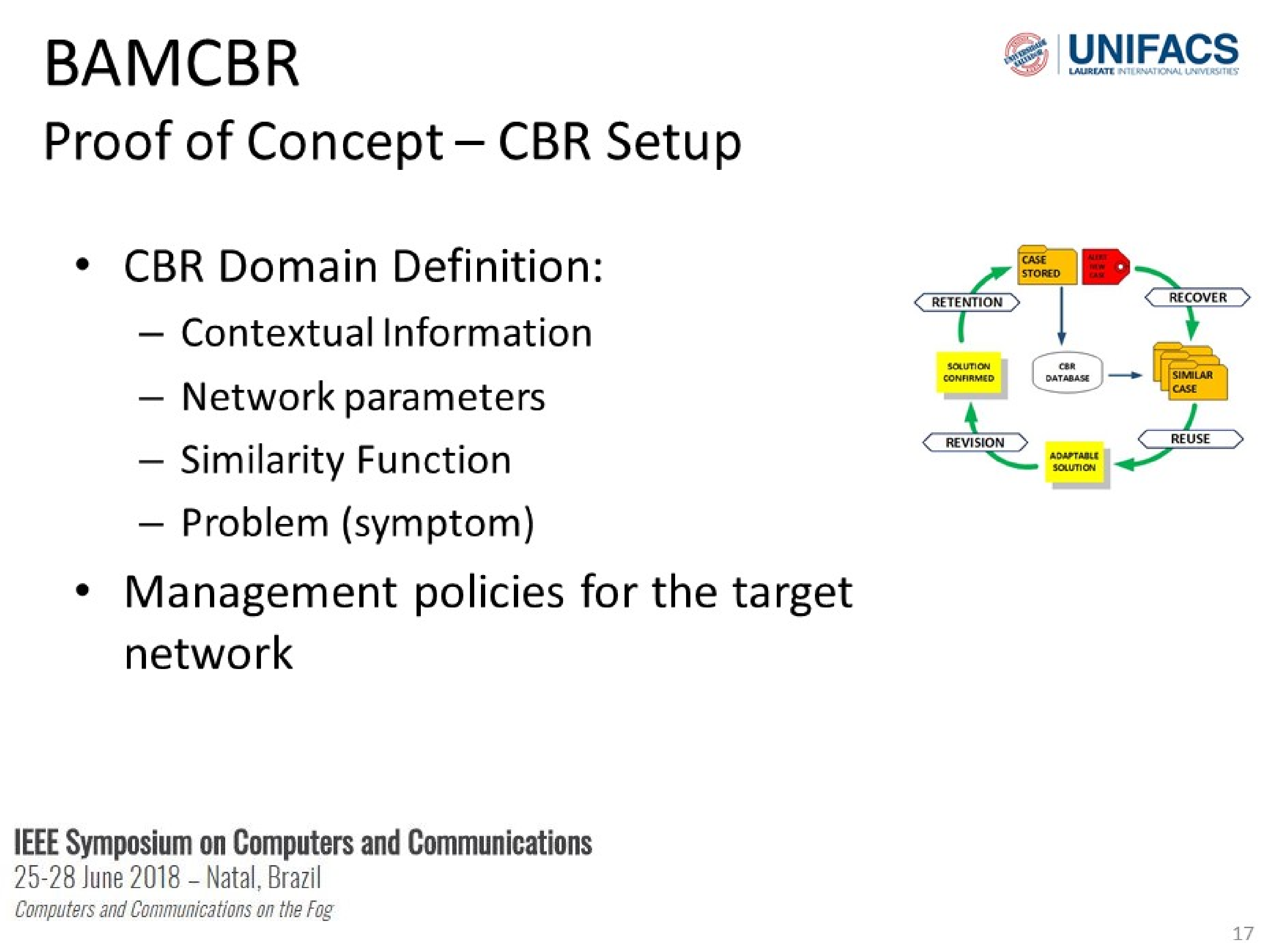


Fig. 17.

−− > **PAPER TEXT EXTRACT**:

"BAMCBR requires two data input sets: network state information (measurements, statistics, etc.) included in the domain definition and the policies/goals of the network manager.

i) Contextual Information - Contextual attributes are related to the current network configuration and the policies defined by the network manager. They identify the context in which similarity should act and their information is acquired before the network optimization process starts. Examples of contextual attributes are: BAM currently used, network manager tolerance for network problems (preemption, devolution, blocking, etc), bandwidth defined for each BC, among others.

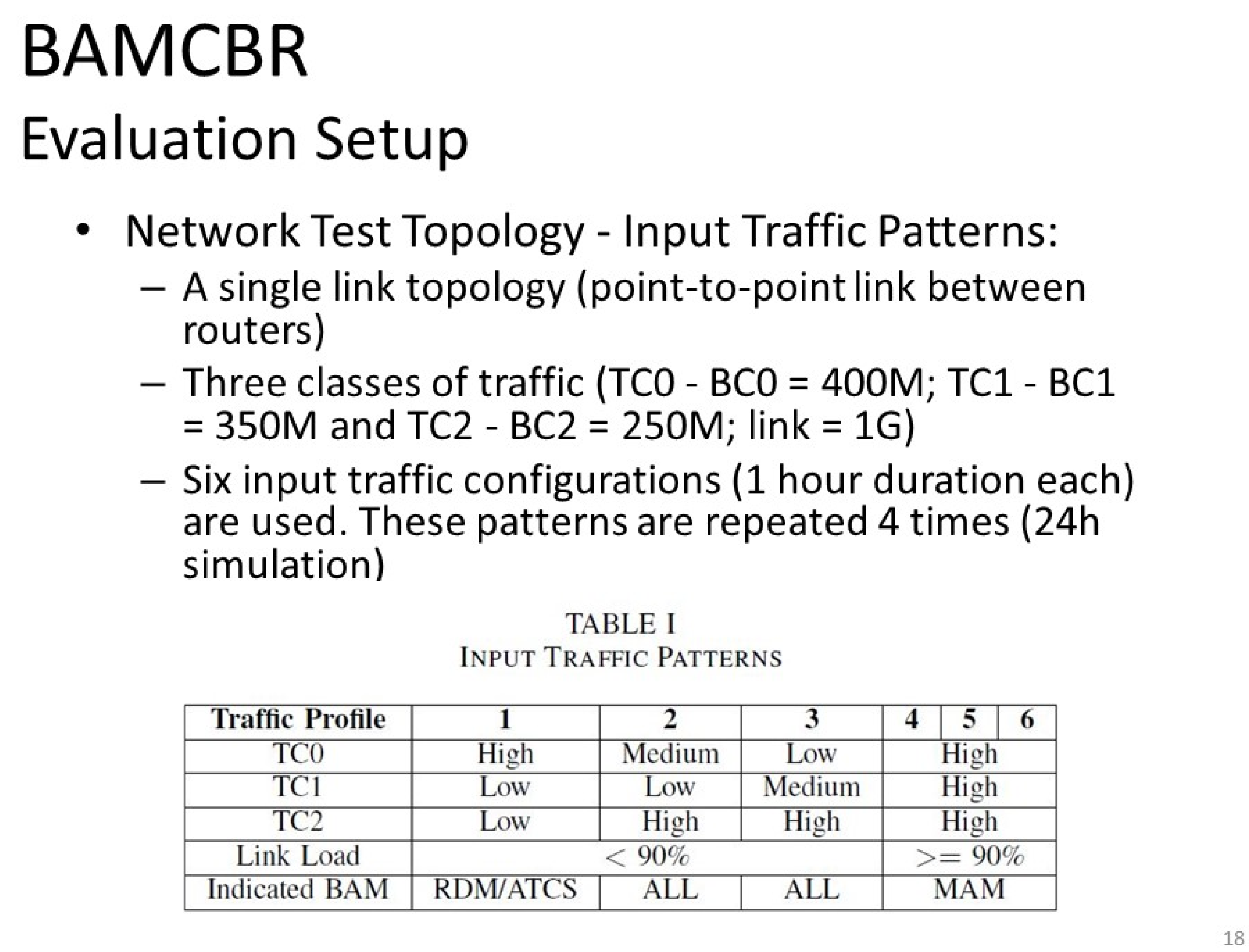
ii) Measurements - These are information obtained from the network and provide a snapshot of the current state of the network. These measurements are essential to portray changes in the network profile. Some examples of measurements are: total or by TCs network utilization, total or by TCs preemption, total or by TC devolution and total or by TCs LSP blocking.

iii) Similarity Function - It is the method used to execute the case's search in the database. One or more similarity functions can be used. The similarity function is responsible for the comparison of cases. Examples of similarity functions are: linear, ladder and nearest neighbor [27].

iv) BAMCBR Problem (symptom) - The BAMCBR problem is the symptom/alert that suggests and characterizes the current problem. These symptoms may be from emergency alerts to setups for periodic diagnoses."

−− > Papers to read:

−− > Complementary papers:



Traffic Profile	1	2	3	4	5	6
TC0	High	Medium	Low	High		
TC1	Low	Low	Medium	High		
TC2	Low	High	High	High		
Link Load	< 90%			>= 90%		
Indicated BAM	RDM/ATCS	ALL	ALL	MAM		

Fig. 18.

−− > **PAPER TEXT EXTRACT**:

"The proof of concept defined is focused on verifying, firstly, if CBR effectively learns and proposes a new reconfiguration and, secondly, if it does achieve any network optimization.

At this point it is worth to remember that BAM models control bandwidth allocation on a per-link basis (independent BAM control and allocation per link). As such, a single link topology (point-to-point link between routers) is used to implement the target MPLS circuit. In a network there will exist various links and the BAMCBR operation will execute independently for all links. As such, the preliminary conclusions obtained about learning capability for this simplified topology will hold true for a more complex topology on a per-link analysis."

−− > Papers to read:

−− > Complementary papers:

Results

TABLE II
BAMs AND BAMCBR PERFORMANCE METRICS

BAM	Preemption	Devolution	Blocking	Unbroken
MAM	0	0	24638	53357
RDM	3813	0	15837	58349
ATCS	3456	2431	7385	64721
BAMCBR	88	158	15523	62226

TABLE III
BAMCBR LEARNING EVIDENCES

BAM	Preemption	Devolution	Blocking	Unbroken
BAMCBR 1/4	30	107	3753	15535
BAMCBR 2/4	62	36	3808	15519
BAMCBR 3/4	11	30	3888	15496
BAMCBR 4/4	11	30	3888	15496

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Fig. 19.

−− > **PAPER TEXT EXTRACT**:
"The proof of concept has 2 phases. In phase 1, each BAM model (Table II) is used statically (no reconfiguration) for a 24h simulation period. Following that, BAMCBR is used to configure BAM models for the same 24h simulation period and input traffic pattern (CBR - Table II). Performance metrics are captured, allowing to compare BAMs individual network performance metrics with CBRBAM cognitive management and infer about the learning process.
In phase 2, CBRBAM pilots BAM reconfiguration process for a 24h period and the objective is to infer further details about the learning process with CBR (Table III).
BAMCBR uses the following management goals and requirements:
i) to minimize preemption and devolution; and
ii) to maximize network utilization in terms of achieving the maximum possible number of established LSPs. For all simulations using BAMCBR, MAM is always the initial BAM model configured and the "cases database" is empty (no previous manager's knowledge is inserted)."

−− > Papers to read:

−− > Complementary papers:

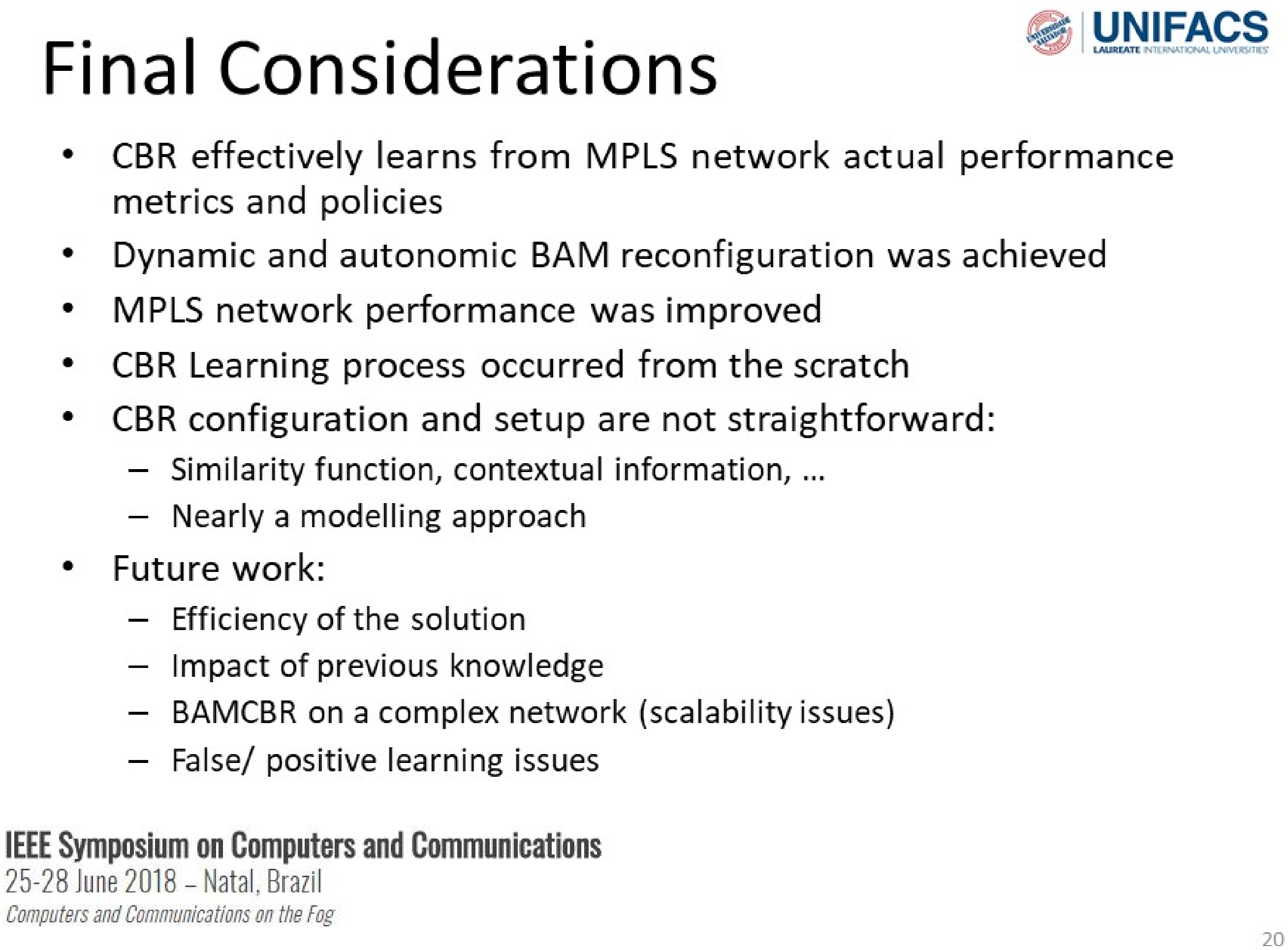

Fig. 20.

-- > **PAPER TEXT EXTRACT**:
"The main evidence obtained for BAMCBR approach is that cognitive management using CBR does learn from policies defined by the manager and from network actual performance metrics. It checks whether the current configuration is adequate and, subsequently, is able to dynamically and autonomically reconfigure BAM models to achieve the specified manager's goal. Another relevant result obtained is that network performance was improved in alignment with manager's predefined policy.
A positive aspect of the result obtained is that the learning process occurred from the scratch. No previous knowledge was required to be inserted in the "cases database" to allow BAMCBR switch among BAM models, looking for the best configuration and find the best possible result. The drawback of not inserting any previous knowledge is that BAMCBR takes more time to find out the appropriate solution and considers eventually "bad solutions" on the learning path that are subsequently not considered (Table II learning evidences BAMCBR 1/4 to 4/4)."

-- > Papers to read:

-- > Complementary papers:

Fig. 21.

−− > **SITES TO VISIT**:
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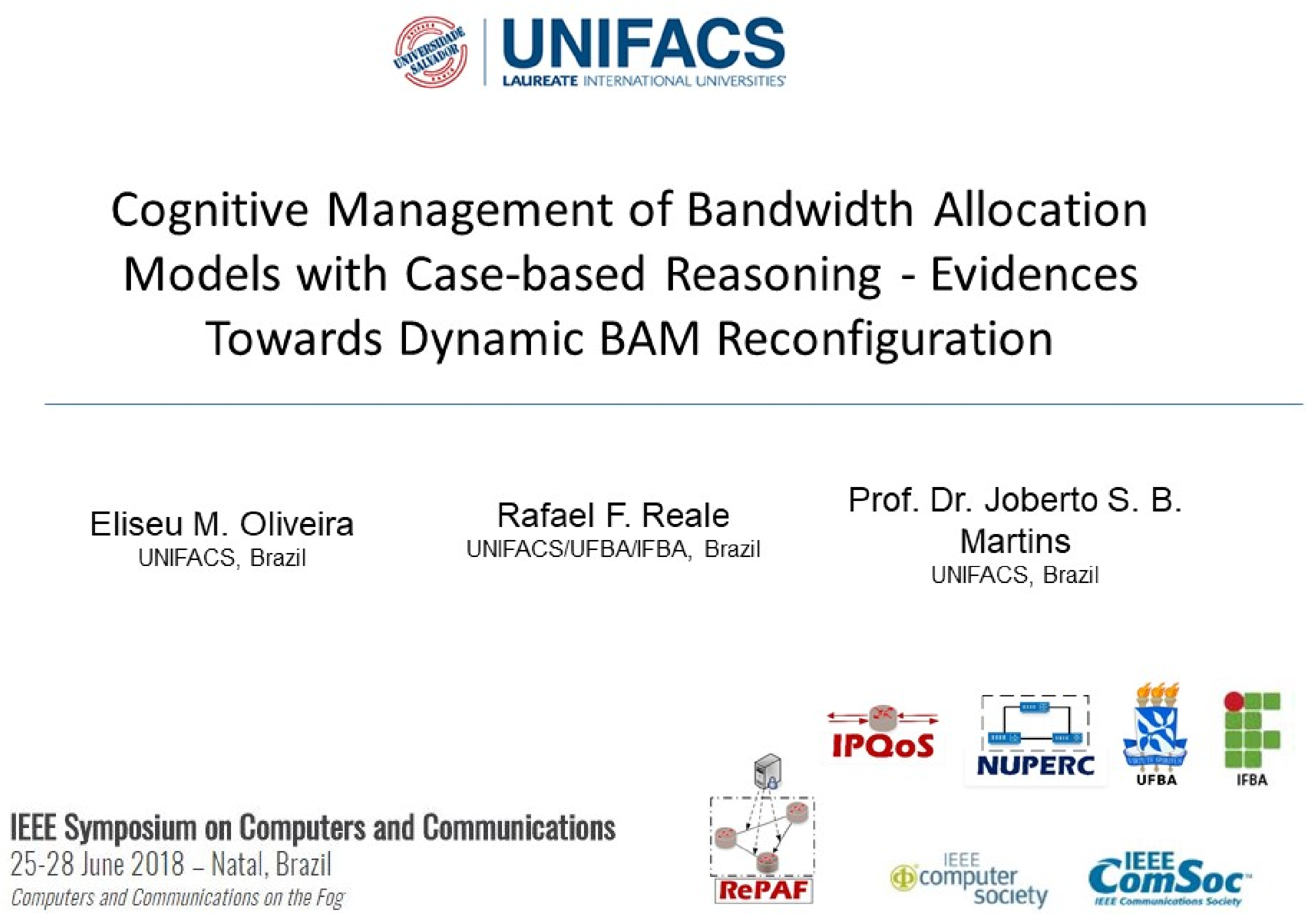
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Fig. 22.

Fig. 23.

−− > Reference [3]

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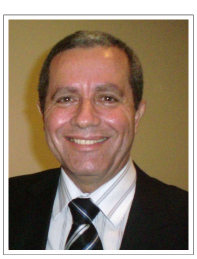

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