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Cognitive heuristics for data dissemination in opportunistic networks

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Including cognitive heuristics in Future Internet protocols will allow users' devices to select information efficiently, achieving a fast and effective dissemination of data in an opportunistic network.

Assessing the relevance of discovered information in the Future Internet will be a very challenging task. Increasing the level of active user participation in content creation and diffusion will risk making the Future Internet a congested information scenario. Users could be deluged by the huge amount of available data from disparate sources. To avoid this situation, devices acting in such an environment will have to determine the relevance of discovered content and select the most interesting data with respect to their users' current interests, as shown in Figure 1. Acting as proxies of human users, they will have to sort out only data that are expected to be useful, without having the complete knowledge required for thorough evaluation. Moreover, to be effective, devices will have to react rapidly to new data items, because a considerable part of the data will also be dynamic and contextualized, such as being relevant only at specific times or in specific geographic areas and of interest only to specific user groups.

One way to overcome these problems is to add autonomic capabilities to the devices. Within the European Union's Seventh Framework Programme—Awareness Recognition project, we are focusing on what we believe is a new direction in autonomic networking. We are exploiting the results from cognitive psychology and some of the key processes that allow human brains to effectively solve the problem of information selection and acquisition.

When faced with large amounts of data, human brains can swiftly react to stimuli and assess the relevance of discovered information with respect to the individual's needs and context. This ability relies on so-called cognitive heuristics, which are rapid, adaptive, low-resource demanding, yet effective schemes that allow the brain to tackle complex problems.[1] They use simple decision rules that need low computational resources and

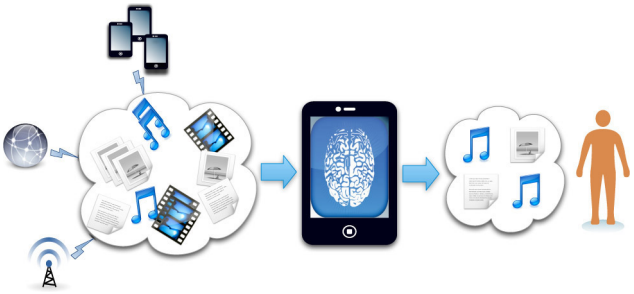

Figure 1. *Cognitive-based capabilities allow Future Internet devices to select relevant information among huge amounts of data.*

computing time, allowing the brain to promptly react to new events. Cognitive psychology describes how these heuristics work and how humans are able to be aware of their environment and make appropriate decisions. The cognitive psychological theory describes these processes through mathematical models that provide a black-box description of a cognitive process's functional behaviour. These models can be used to transfer into the information and communications technology domain the required new mechanisms that allow self-awareness capabilities, which in turn enable enhanced content acquisition in a content-centric Internet. This approach goes well beyond conventional bio-inspired networking solutions. In our approach, the devices are proxies of their human users in the cyber world, and therefore apply the same cognitive functions to become aware of the environment and to make appropriate decisions.

One of the simplest heuristics is the recognition heuristic.[2,3] It is based on a very simple rule. When evaluating a couple of objects, if the brain recalls that it heard about one of the objects (recognizes it) but recalls nothing about the other one, this heuristic infers that the recognized object has a higher value with respect to a given evaluation criterion. People tend to rely on this heuristic when the real criterion value is not available or not

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known. The recognition heuristic has been tested and evaluated as a support in decision-making processes,[4] and proved to be successful in fields such as financial decision-making[5] and forecasting of future purchase activities,[6] sports results[7] or political election outcomes.[8]

We propose[9] exploiting the recognition heuristic for opportunistic information diffusion in a mobile scenario in which nodes want to retrieve all the data on topics that interest their users while devoting only a little memory space for a collaborative information exchange. First, we defined which requisites are needed to implement the recognition heuristic. This allowed us to determine the main variables involved in this process and to design an algorithm by which the recognition heuristic can be implemented by an opportunistic network's nodes. Essentially, recognition is performed using a threshold-based memory for each variable, as suggested by the cognitive psychology literature, whereby a counter is associated with encountered data items and incremented each time the data item is seen again. The item is recognized as soon as the counter reaches a certain threshold. Next, we defined an algorithm that allowed nodes to efficiently combine multiple instances of the recognition heuristic. This algorithm was a modified version of the cognitive psychology 'Take the Best' algorithm, which is used to assess the relevance of available data objects, thus deciding what to store and what to drop.[10]

Simulation results showed the approach's potential and highlighted how correct tuning of the heuristic parameters led to a fast and highly effective dissemination of data. In particular, our approach can achieve effectiveness comparable to more conventional data dissemination approaches in opportunistic networks, while significantly reducing the associated resource usage cost.

In conclusion, exploiting algorithms based on cognitive heuristics promises to be a new, sensible direction and an effective way to cope with scalability issues in mobile Future Internet environments. One of the key topics for our future research will be a complete understanding of the role parameters play on data dissemination efficiency. Another will be understanding how data dissemination works when additional context information, such as social relationships between users, is exploited.

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