THE ARCHITECTURE OF A SOFTWARE MODULE SUPPORTING VERTICAL HANDOVER IN HETEROGENOUS NETWORKS

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***Abstract* – In this paper, the architecture of a software module that can support vertical handover in heterogeneous networks is presented. The proposed approach, is capable of supporting 802.21 link layer events and commands, and represents the start-up point for building a system compatible with the standard, that can be integrated in mobile terminals applications, to provide full mobility to them.**

***Keywords* – vertical handover, interoperability, IEEE 802.21 standard**

1. INTRODUCTION

One of the key challenges in realizing the industry vision of convergence is enabling mobility between heterogeneous access technologies (e.g. Cellular, WLAN). Numerous standardization activities are currently underway to develop a variety of mobility solutions offering a range of nomadic to seamless capabilities for today's convergent architectures.

However, the overwhelming trend (and central to convergence) is the move towards All-IP systems [2]. Today's systems are only beginning to fully embrace IP technology and today's mobility solutions are of course tailored towards these solutions [3]. Emerging architectures such as that envisioned by 3 GPP LTE will be based on All-IP technologies, most notably Mobile IP and SIP. These protocols enable only limited mobility capabilities by themselves. However when complemented with an emerging IEEE standard, IEEE 802.21, then a full mobility solution including seamless handover capability is realized.

Following this development, the RIWCoS (Reconfigurable Interactive Wireless Communications Systems, SfP-982469) project was proposed into Science for Peace NATO framework, focused on the communications issues in emergency cases. Later a new research project was started (Wireless Hybrid Access System with Unique Addressability – SAWHAU, no. 12-126/2008, funded by Romanian Government through the National Company for Project Management) focused on optimizing an hybrid wireless access network in order to reduce or, at least, to optimise the wireless communications access costs for small and medium enterprises [4][5].

Both of these projects are considering the IEEE 802.21 standard [1] and its Media Independent Handover (MIH) concept as the main technological solution to solve their main objectives.

The purpose of the IEEE 802.21 standard is to ensure seamless handover for a mobile unit between networks corresponding to IEEE 802 set of standards and 3GPP/3GPP2 standards. In particular, these types of mechanisms presented in the IEEE 802.21 standard can be used also for handover in homogenous networks, not only in heterogeneous ones.

This new standard was finalized in November 2008 based on the D14 draft version which was approved. But this version is focused on the background features, so new tasks are now open: the 802.21a group focused on security and authentication issues, as well as 802.21b, proposed for interworking between access networks and broadcasting networks (especially DVB-T/H).

Inside the RIWCoS project, we have developed a software module, the Link Interoperability Module, that communicates with the network interfaces to control them and generate events compatible with the standard. These actions are layer 2 specific.

The Media Independent Handover (MIH) functionality facilitates handover decision making, by placing itself between the network dependent link layer and upper layers that make this decision based on messages from MIH Functions (MIHF).

The proposed RIWCoS Link Interoperability Module represents an unified, generic, media independent, link layer interface (MIH_LINK_SAP) between the MIHF (Media Independent Handover Function), presented in [6][7][8] and the media dependent, link layer, network interfaces.

Besides adapting different media dependent link layer management interfaces to a common media independent interface, the Link Interoperability Module realize other link management related activities, supported by the internal components described as follows.

Fig. 1 shows the role of Link Interoperability Module [6][7][8] inside a system (RIWCoS) capable of supporting 802.21 functions. The superior layers can communicate with every network interface, not knowing its technology type. The technologies desired to be included in the final system, are at first 802.11, 802.11, 802.15, 802.16 and 3G and 3GPP.

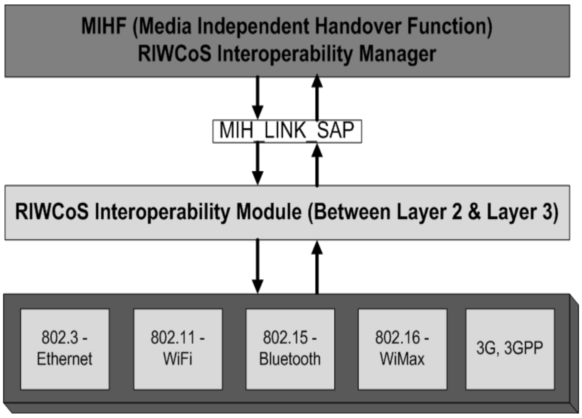

Fig. 1 – RIWCoS Link Interoperability Module Position

The structure of the paper is organized as follows. Section 2 briefly introduces the general architecture of the proposed solution. Section 3 explains how the various internal components are interconnected. Section 4 presents a short description of the main components. Section 5 shows a typical usage scenario that depicts the behavior of the proposed module. Section 6 gives some concluding remarks.

2. GENERAL ARCHITECTURE

Since 802.21 Link Layer primitives do not have the same functionality, the RIWCoS Link Interoperability Module has to be formed of several blocks, each having independent functionality. The goal of this paper is to present the general architecture, to define the major blocks composing the module, and to illustrate the methods of interconnection between them.

The description given in [1], regarding MIH_LINK_SAP primitives, leads us to split them into the following categories:

- Command primitives
- Event primitives
- Service control primitives

We could have defined 3 blocks for the interoperability module, each with the task to handle one set of primitives. However, if we had proceeded like this, the independence degree would have been relatively small.

That is why we defined 3 major functionalities for the RIWCoS Link Interoperability Module:

- Action Handling
- Parameters Handling
- Events Handling

The proposed module, is responsible for managing parameters of the known links, of raising events and passing them to the superior levels of the global architecture, and to perform actions like connecting to, disconnecting from a given link.

The defined blocks have to run in parallel and that is a reason for choosing to implement message queues, acting as buffers. We also need a data structure in which we can record every link characteristics an. To interconnect the 3 major blocks that perform the above mentioned functionalities, we are in need of a block that will receive messages from higher level entities, and that will dispatch the corresponding primitives to the responsible block.

The global view of the architecture for the RIWCoS Link Interoperability Module is presented in the below Fig. 2. As shown in the drawings, the major blocks composing the interoperability module are:

- *Action Manager* – Manages primitives that command actions on different links (Connect, Disconnect, Etc…)
- *Events Manager* – Raises the events related to link states (ex. A mobile host moves towards the end of the signal coverage area and this entity launches a Link Going Down event for the communication’s link)
- *Parameters Manager* – This entity manages the link parameters section. Every link needs to have some thresholds in order to predict if the link is trustworthy for a new communication session. This block is responsible of extracting and managing the link parameters and thresholds.
- *IM Command Dispatcher* – Dispatches the commands to the block responsible of their processing. Inside the prototype developed to demonstrate the capabilities of the RIWCoS Link Interoperability Module, the command dispatcher has the task of formatting the received messages according to 802.21 standard.
- *Link Records Data Structure* – Data block, needed to store information about known networks, their parameters, thresholds, credentials, etc. Every manager has action to a part of this data structure, represented inside Fig. 2, like small blue blocks.
- *Message Queues* – The message queues have the role of assuring parallel processing for the blocks. They have to be designed to be efficient at high number of requests.

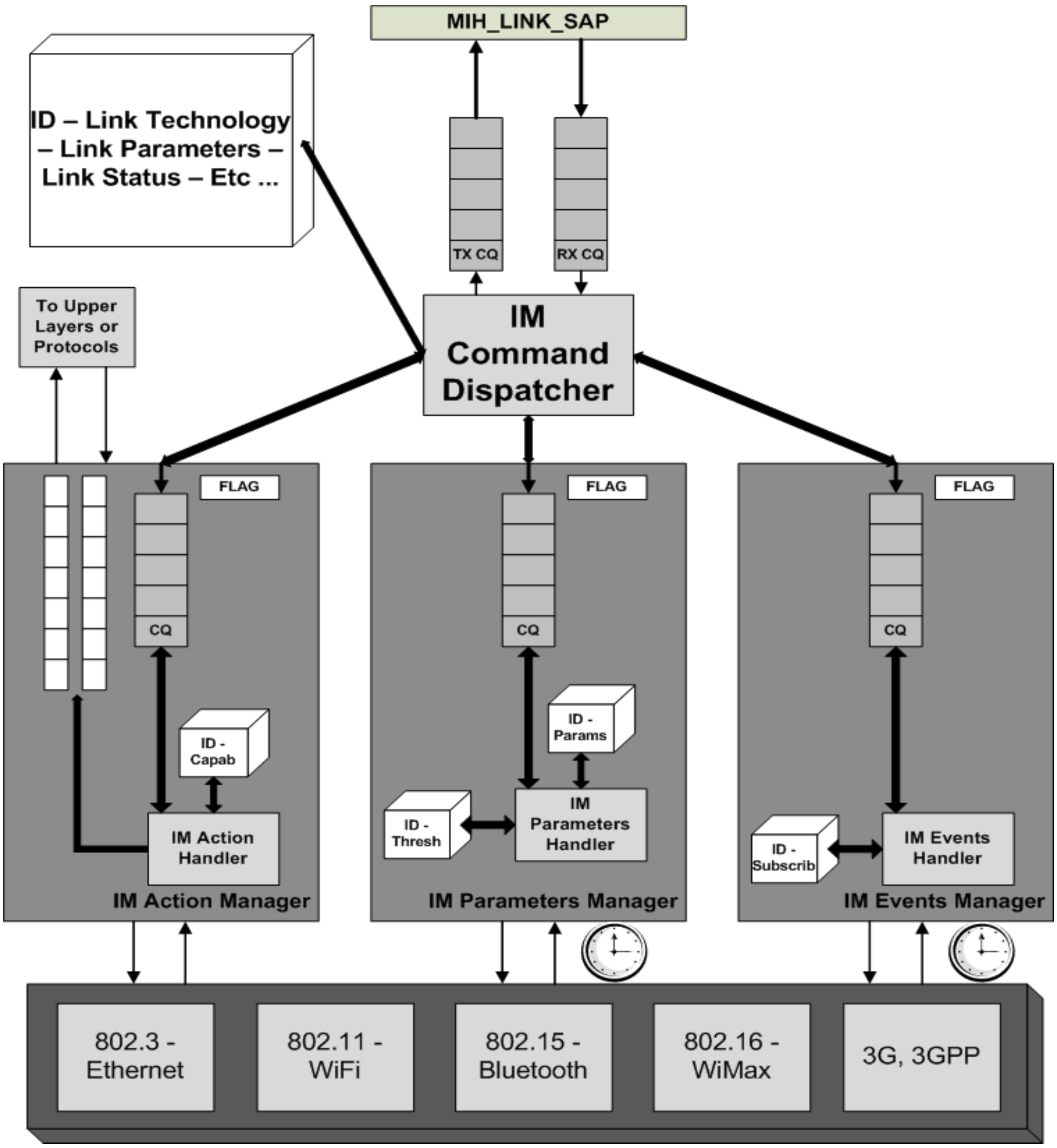

Fig. 2 – Link Interoperability Module Global Architecture

3. COMPONENTS INTERCONNECTION

Interconnecting the three internal managers is the mainly task of the IM Command Dispatcher. Also the command queues bring their effort to it.

The command dispatcher, periodically scans the RX Queue, filled with messages from higher level protocols, and it categorizes these messages by their ID.

After that, it formats the received data according to 802.21 standards, and pushes the new message inside the queue of the handling manager.

To fill the TX Queue, the IM Command Dispatcher, scans the TX queues of every manager, and if a new response arrives inside one queue, it extracts it and sends the data back to higher entities. Fig. 3, represents a state diagram for the presented sub-block behavior.

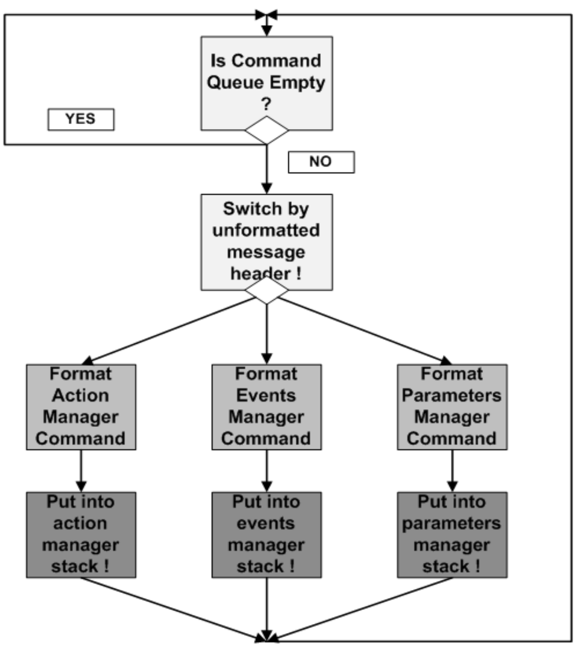

Fig. 3 – IM Command Dispatcher State Diagram

The results obtained by the processing inside the managers, are centralized inside a data structure that has to have the fields shown in in Fig. 4.

Field Name	Field Type	Rec 1	...
ID	*Int*		
Link Name	*String*		
Link Technology	*Byte*		
Link State	*Byte*		
Link Parameters	*Address*		
Link Thresholds	*Address*		
Link Event Capabilities	*Int*		
Link Command Capab.	*Int*		

Fig. 4 – Link Records Table (IM Data Structure)

A link record is uniquely identified by it-s **ID**. The **Link Name** field represents the name of the access point or just the name of the connection. **Link Technology** field can be filled with the ID of one of the technologies integrated inside the final system (WiFi, WiMAX, Bluetooth, 3G, 3GPP).

Link Parameters field is a pointer to a structure containing the QoS (signal strength, data rate, etc...) parameters for the specified link.

Link Thresholds is a structure of the same type as the one used for **Link Parameters** that contains the thresholds for the link. **Link Event Capabilities** field is a set of flags that contain information about the events that can be raised by that link. For example the fifth bit of the value written for a link inside this field, can signify if the link could raise an event of type "Link Going Down".

The **Link Command Capabilities** field is the analogue field to Link Event Capabilities, but containing the flags specifying the commands. We implemented the Link Records Table, as an array of structures, having as fields the ones described in the above paragraph. Fig. 5 represents the data structure, as used by the developers who built the RIWCoS Link Interoperability Module.

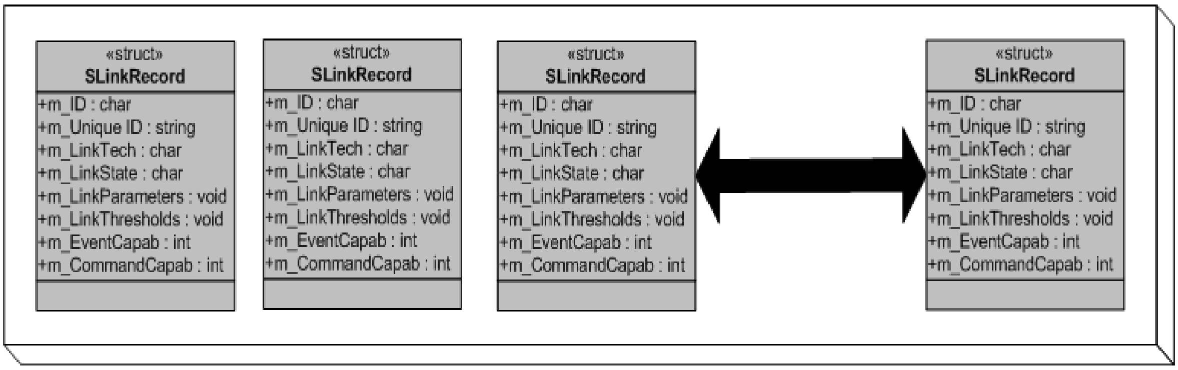

Fig. 5 – Link Records Table (Structures array)

4. PRIMITIVES MANAGERS

4.1. Action Manager

The action manager block, is responsible for primitives related to the handover state, for connection and disconnection commands and for service control messages. The following 802.21 messages will be dispatched to the Action manager:

- *Link Action* – Can be Connect or Disconnect. It needs to receive as input arguments, the link identifier, the action identifier and an execution delay.
- *Link Handover Imminent* – This event will be raised when the handover procedure has been initiated.
- *Link Handover Complete* – This link event will occur after the handover has been completed.
- *Link PDU Transmitted* – Occurs when a protocol data unit has been transmitted and the status (success / failure) of the transmission is being signaled.

4.2. Events Manager

The Events Manager block, has the task of raising the events preceding the vertical handover, and to manage the recorded links abilities to raise such events and to respond to certain commands.

It is also responsible for signaling when a new point of access was found, and when a link was established or lost. From the 802.21 link layer messages, the Events Manager, handles the following:

- *Link Up* – Occurs when a new connection on a registered link has been established.
- *Link Down* – Occurs when a connection was closed.
- *Link Detected* – The event is raised when a new point of access was discovered. A summary report containing the link name, the technology and some QoS parameters is being sent to be processed.
- *Link Get Capabilities* – It represents a command and it requests the capabilities of a given link (events capabilities and command capabilities).
- *Link Events Subscribe* – This command subscribes a given link to a set of events (and commands), giving the link the possibility of raising the selected events or to respond to the commands.
- *Link Events Unsubscribe* – It represents reverse command of the previous one.

- *Link Going Down* – This notification is the result of advanced prediction algorithms based on link parameters evolution; signifies that a link is suspected to lose its signal.
- *Link Event Rollback* – Occurs when predicting the Link Going Down event has failed, and all the procedures that took place after that notification, need to go down.

4.3. Parameters Manager

The Parameters Manager handles all primitives related to the links parameters and their thresholds.

From the primitives respecting IEEE 802.21, the IM Command Dispatcher will send the following to the current block:

- *Link Configure Thresholds* – It's a command having as parameter an address which stores the thresholds for a given link. These thresholds will influence also the prediction algorithms.
- *Link Parameters Report* – It's a report that is being sent to higher level entities, each time a timer consumes it's refresh period.
- *Link Get Parameters* – This command is a request for certain parameters and certain link states.

5. TYPICAL USAGE SCENARIO

Fig. 6 presents a typical usage scenario of the proposed Link Interoperability Module.

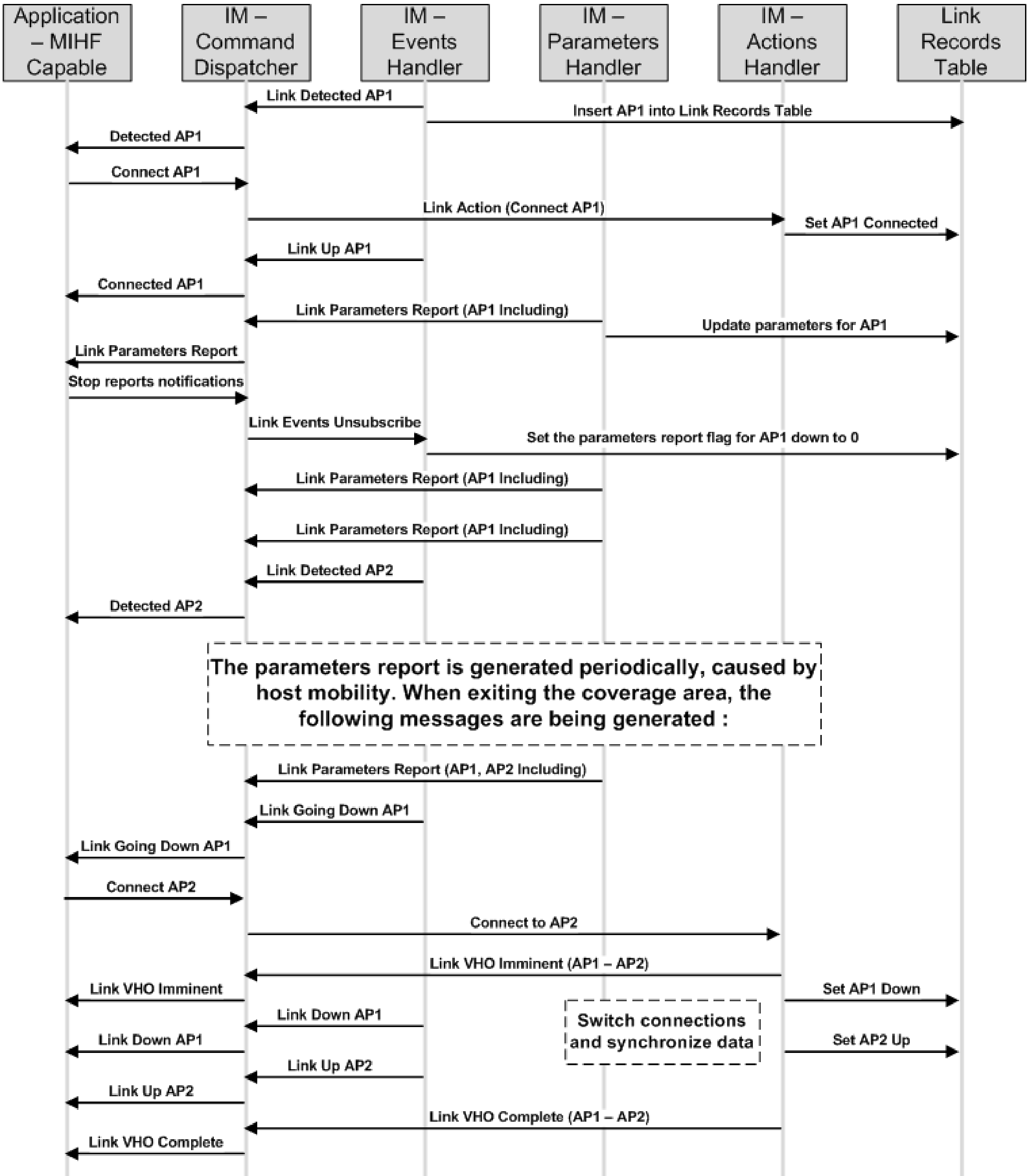

Fig. 6 – Typical Usage Scenario of the Link Interoperability Module

The usage scenario when performing vertical handover, occurs when a mobile host loses quality on the current link, and it has the possibility of connecting to another link, with better QoS parameters.

In Fig. 6, we exemplified a simple message sequence chart, that shows how the RIWCoS – Link Interoperability Module components interact in order to produce the handover. At first the mobile host connects to a known link (AP1), with good communication parameters.

When connected, the Parameters Manager periodically reports the quality of links, registered in the link records table. If we want to stop receiving report notifications, we can unsubscribe from this event.

When the signal quality is falling below a threshold, and the link is predicted to go down, the handover to AP2 is being initiated by the application. The Action Manager realizes the connection switch, and sends further the messages.

6. CONCLUSION

This paper describes the software architecture of a Link Interoperability Module, supporting vertical handover, for mobile terminals that have possibilities of accessing multiple telecommunications technologies. The presented architecture complies with IEEE 802.21 standard, referenced in [1].

Our goal was to build a module that will fit to an Interoperability Manager (implementing the IEEE 802.21 MIH Function) in order to raise the link layer events, and also to perform the commands given by user applications.

We introduced the general architecture of the proposed solution, gave some explanations on how the various internal components are interconnected, presented a short description of the main components and finally illustrated the behavior of the proposed module by means of a typical usage scenario.

The next step in our work will be the integration of the module into a framework that will comprise Interoperability and Resource Managers into the RIWCoS system, whose high level design is presented in [4].

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