Semantically Enriched Services to Understand the Need of Entities

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Abstract. Researchers from all over the world are engaged in the design of a new Internet, and Software-Defined Networking (SDN) is one of the results of this engagement. Net-Ontology uses a SDN approach to bring semantics to the intermediate network layers and make them capable of handling application requirements and adapt their behaviour over time as required. In this paper we present an experimental evaluation of Net-Ontology and a feature comparison against the traditional TCP/IP stack. This paper extends our earlier work towards a Future Internet, showing a viable approach to introduce semantics at network lower layers by contributing to bring richer and efficient services.

Keywords: Future Internet, Enrich Services, Network Ontology, SDN, DTS, Workspace.

Introduction

The evolution of the intermediate network layers have been lagging behind that of the lower and upper layers. The Internet Protocols, specified more than three decades ago, are the likely culprit; the application needs have changed by leaps, while the TCP/IP has only been patched, trying to meet these requirements. Over the last few years, the networking community has strived to correct this phenomenon[1, 3, 4, 21].

Researchers from all over the world are engaged in the design of a new Internet, from the ground up. This so called *clean slate* approach, frees the research from the legacy of the current architecture and fosters innovations[18]. At a future time, when results should be deployed, the research will then be refocused to the transition from the current Internet to the future Internet

One of the results of this effort to create the Future Internet is Software-Defined Networking (SDN)[5, 6]. SDN enables researchers to innovate and experiment new network protocols, naming and addressing schemes, such as the one presented in this paper, which aims at bridging the evolutionary gap between upper, lower, and the intermediate network layers by using a richer semantics [15, 16].

FINLAN (Fast Integration of Network Layers) [9, 13, 14, 19] aims at providing high adaptability through the use of semantic concepts based on ontology, with the elimination of static routing and addressing tied to physical location, resulting in a better and efficient utilization of the network infrastructure.

FINLAN defines two intermediate layers that communicate between each other using OWL (Web Ontology Language), but that clearly differentiate in function: DL-Ontology and Net-Ontology.

The DL-Ontology layer is essentially responsible for data transfer between the Physical layer and the upper layers, handling the semantic communication between the peer entities and bringing a richer capacity to express their requirements. On the other hand, the Net-Ontology layer is accountable for handling service needs, as it is capable of understanding specific requirements from the application and adapting the communication to support them only when required, using DL-Ontology to deal with the semantic communication.

In this chapter we present the Net-Ontology layer, which sits between the DL-Ontology layer and the application. We also present its implementation and a first experimental evaluation. The implementation presented is based on the Title Model[17], our vision regarding future networks.

The remainder of this work is organized as follows: Section 1 describes the Net-Ontology. Section 2 shows the Net-Ontology implementation and Section 3 the experimental results. The conclusions are presented in Section 4.

1 The Net-Ontology

The DL-Ontology is the lower layer of the FINLAN stack depicted in Figure 1, and enables the communication using concepts expressed in OWL over the Physical layer.

The Net-Ontology layer is responsible for supporting the service needs of the upper layer and deliver them to the DL-Ontology layer, built according to the FINLAN Ontology. In this approach, the Net-Ontology is able to understand specific requirements of a given application that may arise over communication and provide them.

For example, let us suppose that two persons, P_1 and P_2, are chatting over the Internet, using the application *FinChat* that runs over the FINLAN stack. In a certain moment, they want to start a secret conversation. To *FinChat* meet this need, the only thing it has to do is to inform the Net-Ontology layer that from now on the chat is to be confidential. The Net-Ontology layer is able to understand this need and act accordingly modifying all packets exchanged from that moment.

The Net-Ontology consists, basically, of two main modules: *requirement analysis* and *requirement manager*, as depicted in Figure 1.

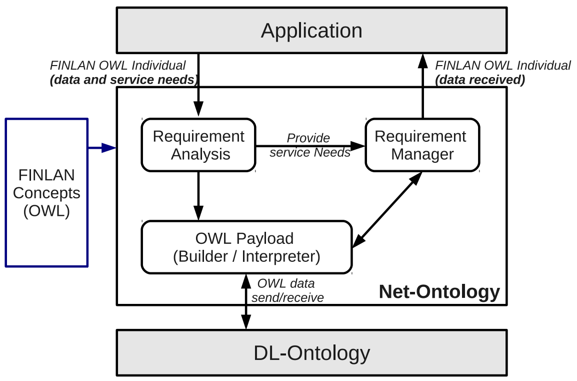


Fig. 1. Net-Ontology modules

The *requirement analysis module* (RAM) is responsible for handling the application requests regarding communication requirements. To accomplish this, RAM uses the Leśniewski's logic as proposed in [8]. The purpose is to manage the services requirements over time. This module recognizes what technological features are necessary to satisfy a given requirement, in a given moment, combining them in logical formulas.

As an example, let us suppose that a service $S1$, in a moment t_1, may need to establish communication with the service $S2$, with a specific requirement. The RAM will verify that this upper layer requirement can be provided by the technological requirements $R1$ and $R2$. In another moment t_2, $S1$ wishes to improve security, using confidentiality in the conversation. For so, it is necessary the technological requirement $R3$. These scenarios will be interpreted by the analysis module and represented by the following axioms:

$$S1S2t_1 \to R1 \wedge R2 \tag{1}$$

$$S1S2t_2 \to (R1 \wedge R2) \wedge R3 \tag{2}$$

The *requirement manager module* (RMM) takes the rules requirements and transform them into FINLAN ontology fragments. Besides that, this module is able to interpret and deploy the algorithms correlated with each requirement of the ontology in the network stack.

Taking the aforementioned example, in the moment t_1, RMM receives the requirements $R1$ and $R2$ from RAM. It will then use the FINLAN Ontology, and add to the packages an OWL fragment, representing that P_1 has requirements R_1 and R_2 in *FinChat*.

From now on, the packages will be transmitted containing new information. When the *FinChat* of P_2 receives an OWL package, meaning that $R1$ and $R2$ are required, the RMM will be able to understand and make use of the necessary algorithms. The intelligence for the network to understand and implement the applications needs is the main responsibility of the *requirement manager module*.

The requirements, manipulated by RAM, are stored at the Domain Title Service (DTS), which consists of a distributed system over the network elements responsible for maintaining the entities available in a domain and their communication requirements over time. It plays an important role at central aspects of networking like naming and addressing, and has the ability to share the context among communicating entities. This sharing is provided by the workspace.

The workspace is a logical bus which contains network elements required to support the communication of the entities. The workspace is created by an entity wiling to communicate with a specific purpose and thus defines its requirements and capabilities. A new entity can be joined to an existing workspace and, in such event, the logical bus can be adapted to handle its communication.

All entities that shares a workspace takes part in the same communication. The data is sent once by a source to the workspace and is received by all the others, thus making an efficient use of the physical layer.

In the next subsection it will be presented a complete case of how the Net-Ontology modules interact with the others FINLAN layers and the DTS.

1.1 FINLAN Semantic Communication

The communication between the FINLAN layers occurs in a semantic way, by using OWL. Below, it is presented an example to illustrate how this communication happens.

Let us suppose a scenario where *John* and *Paul* are chatting using the application *FinChat* that runs over the FINLAN layers, through the workspace WKS.1. In a first moment t_1, they are just talking about irrelevant issues and are not concerned about any additional feature that *FinChat* can offer to them. So, the packages travelling in the network are very simple, and the Net-Ontology has not introduced any new requirement at the communication, in this case, only the DL-Ontology handles their communication. A code snippet example can be:

```
<Message rdf:ID="Message_1">
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Paul</
            source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            John</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#byte">Hello!
            How are you doing??</payload>
</Message>
```

After some time, at instant t_2, *John* starts an important subject, and selects the feature *delivery guarantee* of *FinChat*. This means that from now on, *FinChat* requires delivery guarantee to the network. The Figure 2 shows the messages flow that will be sent and received between the *FinChat* entities and the DTS, to attend this request.

With a new requirement, the Net-Ontology layer is triggered, and the *requirement analysis module* checks that it is necessary the technological requirement of a delivery guarantee algorithm. *John*'s *FinChat*, then, sends the following control message to DTS:

```
<ControlMessage rdf:ID="ControlMessage_1">
        <Application rdf:ID="FinChat">
                <HasNeed>
                        <DeliveryGuarantee rdf:ID="DeliveryGuarantee_01"/>
                </HasNeed>
        </Application>
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">John</
            source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            DTS</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            AddNeed</payload>
</ControlMessage>
```

After registering *John*'s need, the DTS will send him a confirmation message:

```
<ControlMessage rdf:ID="ControlMessage_1R">
        <Application rdf:ID="FinChat"/>
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">DTS</
            source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            John</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#string">OK</
            payload>
</ControlMessage>
```

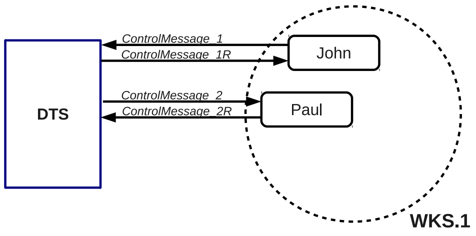


Fig. 2. Message flow example for a new requirement

At the same time, DTS will also send to *Paul*, who is in the same workspace as *John*, a control message, asking if the need requested is supported:

```
<ControlMessage rdf:ID="ControlMessage_2">
        <Application rdf:ID="FinChat">
                <HasNeed>
                        <DeliveryGuarantee rdf:ID="DeliveryGuarantee_01"/>
                </HasNeed>
        </Application>
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">DTS</
            source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            Paul</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#string">isOK<
            /payload>
</ControlMessage>
```

If *Paul*'s *FinChat* can supply the delivery guarantee feature, the response below is sent to DTS and it is established a communication with support to delivery guarantee:

```
<ControlMessage rdf:ID="ControlMessage_2R">
        <Application rdf:ID="FinChat"/>
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Paul</
            source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            DTS</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#string">OK</
            payload>
</ControlMessage>
```

In case of *Paul*'s *FinChat* with no support for the delivery guarantee, this feature will not be present in the communication between both applications.

Notice that through the Net-Ontology, FINLAN is able to register the services needs into the DTS. From now on, it can manage what is the best way to deliver FINLAN packages.

If a third person, *Ringo*, wants to join the conversation, *Ringo*'s *FinChat* will handshake with DTS to check if it has support to DeliveryGuarantee_01. This scenario is illustrated in Figure 3.

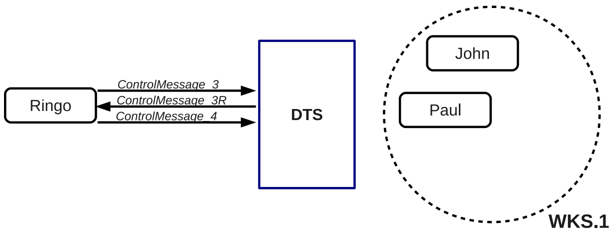


Fig. 3. Message flow example for a Join into Workspace *WKS.1*

The following messages are exchanged and Ringo joins the workspace WKS.1. After the joining and, hence, sharing of the workspace, *Ringo*'s *FinChat* and all the other entities will receive the same data messages without the need of multiple data flows.

```
<ControlMessage rdf:ID="ControlMessage_3">
        <Application rdf:ID="FinChat">
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Ringo<
            /source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            DTS</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Join<
            /payload>
</ControlMessage>


<ControlMessage rdf:ID="ControlMessage_3R">
        <Application rdf:ID="FinChat">
                <HasNeed>
                        <DeliveryGuarantee rdf:ID="DeliveryGuarantee_01"/>
                </HasNeed>
        </Application>
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">DTS</
            source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            Ringo</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#string">isOK<
            /payload>
</ControlMessage>

<ControlMessage rdf:ID="ControlMessage_4">
        <Application rdf:ID="TestApplication">
        <workspaceID rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            WKS.1</workspaceID>
        <source rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Ringo<
            /source>
        <destination rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
            DTS</destination>
        <payload rdf:datatype="http://www.w3.org/2001/XMLSchema#string">OK</
            payload>
</ControlMessage>
```

It is also important to mention that after the exemplified handshakes between DTS and *FinChat* entities, the *requirement manager module* is responsible for guaranteeing that the exchanged packages during the chat will have the necessary information, implementing the algorithm DeliveryGuarantee_01. For example, differently from the *Message_1* structure, the messages must have an identification field, through which the control of lost packages is made.

2 Implementation

Our FINLAN stack implementation consists of a Java library that uses communication interfaces through Raw Sockets. The linking between Java and C portions of the code was done in Java Native Interface (JNI) [16, 19], as depicted in Figure 4.

It is observed that the application *App.java* should use the API available in the library *Finlan.jar* to establish communication. In this way, when an application sends a packet, it communicates with the Net-Ontology sending its characteristics. According to these characteristics, the *Requirement Module Analisys* determines, through an inference engine, the application needs and proceeds

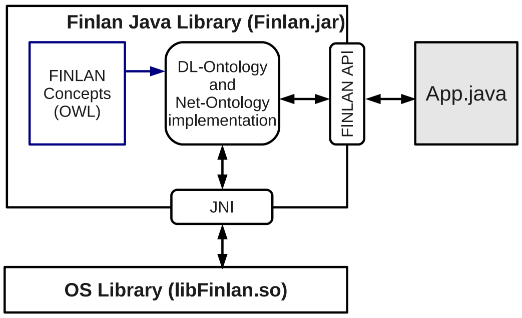

Finlan Java Library (Finlan.jar)
FINLAN Concepts (OWL)
DL-Ontology and Net-Ontology implementation
FINLAN API
App.java
JNI
OS Library (libFinlan.so)

Fig. 4. FINLAN Modules Implementation

with the delivery of these. After the completion of the relevant operations, Net-Ontology sends the primitive to the DL-Ontology which, in turn, takes care of sending the packet through the JNI interface to the *libFinlan.so* library.

3 Experimental Results

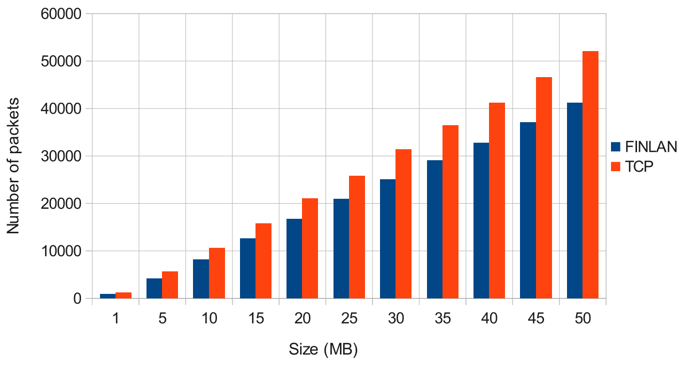
To validate the implementation of this work, it was performed experiments comparing FINLAN with the TCP/IP Architecture protocols. The goal of these experiments was to show the behavior of the ontology use in a file transfer operation with the delivery guarantee need activated, illustrating the use of the Net-Ontology layer in FINLAN.

The TCP/IP protocols, by definition, already implements the delivery guarantee feature, when the TCP transport protocol is used. To FINLAN support this need, this work implemented it in the Net-Ontology layer, using the algorithm described in [14]. This algorithm is a mechanism to ensure that all packages sent are received and works as follows: when the need delivery guarantee is activated by the application layer, all packages, sent from this moment contains a new field representing the number of the package.

In parallel, there is a mechanism of confirmation requests and responses messages: the source host informs the packages already sent, requesting the lost ones. The destination, on the other hand, answers which packages it did not receive. This change of confirmation messages is orchestrated by the RTT variable, proposed in [7], which consists of the best estimate (for that moment) for the send and receive time up of the packets destination.

3.1 Network Traffic Evaluation

The experiments were performed over the following environment: hosts with 4GB of RAM, CPU Intel® Core™2 DUO @ 2.10GHz, running Linux operational system with kernel 2.6.41.10-3.fc15.x86_64. The files transfered have size of 1, 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50MB. The RTT variable was set to a fixed



(a) Number of packets

Size	FINLAN	TCP	Reduction (%)
1 MB	847	1168	37,9%
5 MB	4174	5594	34,0%
10 MB	8140	10631	30,6%
15 MB	12566	15733	25,2%
20 MB	16722	21060	25,9%
25 MB	20920	25277	25,6%
30 MB	25017	31423	25,6%
35 MB	29089	36495	25,5%
40 MB	32786	41143	25,5%
45 MB	37070	46585	25,7%
50 MB	41207	52067	26,4%

(b) Percentual reduction

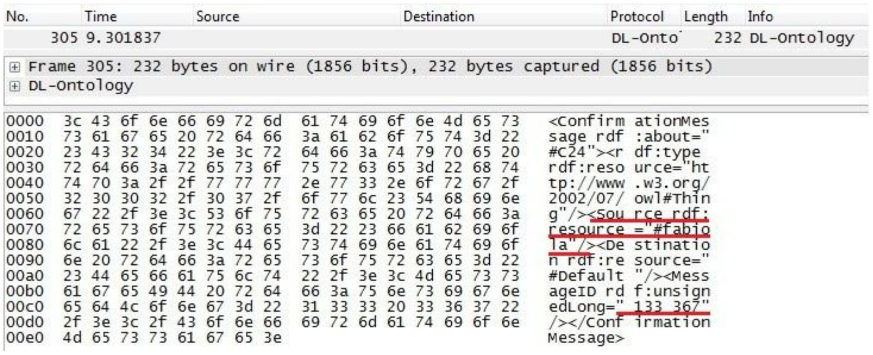
Fig. 5. FINLAN and TCP traffic comparison

value of 1 second. Figure 5 shows the results, comparing the number of packets transmitted in both: FINLAN and TCP.

It is possible to observe that in the scenarios of this experimentation, FINLAN had a smaller number of transmitted packets. In the transfer operation of 10MB, for example, FINLAN transmitted 8140 packets, while the TCP transmitted 10631 (one difference of 30.6 percent).

This is due to the delivery guarantee algorithm implemented in FINLAN that sends confirmation messages in intervals of the RTT, informing only the lost ones, in a period, to be re-transmitted, while TCP transmitted several number of ACK packages. This confirms that the network traffic packets is decreased using the delivery guarantee algorithm implemented over a stack that semantically understands the concepts and adapts the messages from this understanding.

To illustrate the primitives in these experiments, Figure 6 shows snapshots from the Wireshark of two packets captured during the transmission of the 50MB file. The first one, in Figure 6(a), is the confirmation request of the source entity, called "fabiola", informing that the range of packages from 133 to 367 was sent. The Figure 6(b) represents the response, confirming the lost packages, through

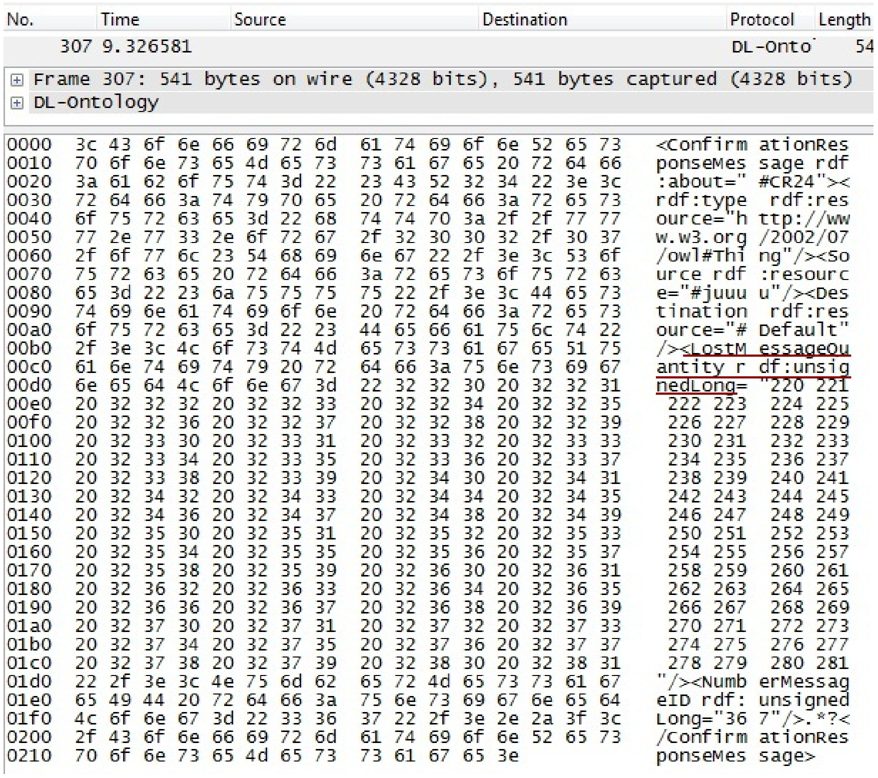


```
No.   Time      Source   Destination   Protocol  Length  Info
  305 9.301837                         DL-Onto      232  DL-Ontology

⊞ Frame 305: 232 bytes on wire (1856 bits), 232 bytes captured (1856 bits)
⊞ DL-Ontology

0000  3c 43 6f 6e 66 69 72 6d  61 74 69 6f 6e 4d 65 73   <Confirm ationMes
0010  73 61 67 65 20 72 64 66  3a 61 62 6f 75 74 3d 22   sage rdf :about="
0020  23 43 32 34 22 3e 3c 72  64 66 3a 74 79 70 65 20   #C24"><r df:type
0030  72 64 66 3a 72 65 73 6f  75 72 63 65 3d 22 68 74   rdf:reso urce="ht
0040  74 70 3a 2f 2f 77 77 77  2e 77 33 2e 6f 72 67 2f   tp://www .w3.org/
0050  32 30 30 32 2f 30 37 2f  6f 77 6c 23 54 68 69 6e   2002/07/ owl#Thin
0060  67 22 2f 3e 3c 53 6f 75  72 63 65 20 72 64 66 3a   g"/><Sou rce rdf:
0070  72 65 73 6f 75 72 63 65  3d 22 23 66 61 62 69 6f   resource ="#fabio
0080  6c 61 22 2f 3e 3c 44 65  73 74 69 6e 61 74 69 6f   la"/><De stinatio
0090  6e 20 72 64 66 3a 72 65  73 6f 75 72 63 65 3d 22   n rdf:re source="
00a0  23 44 65 66 61 75 6c 74  22 2f 3e 3c 4d 65 73 73   #Default "/><Mess
00b0  61 67 65 49 44 20 72 64  66 3a 75 6e 73 69 67 6e   ageID rd f:unsign
00c0  65 64 4c 6f 6e 67 3d 22  31 33 33 20 33 36 37 22   edLong=" 133 367"
00d0  2f 3e 3c 2f 43 6f 6e 66  69 72 6d 61 74 69 6f 6e   /></Conf irmation
00e0  4d 65 73 73 61 67 65 3e                            Message>
```

(a) Confirmation request



```
No.   Time      Source   Destination   Protocol  Length
  307 9.326581                         DL-Onto      54

⊞ Frame 307: 541 bytes on wire (4328 bits), 541 bytes captured (4328 bits)
⊞ DL-Ontology

0000  3c 43 6f 6e 66 69 72 6d  61 74 69 6f 6e 52 65 73   <Confirm ationRes
0010  70 6f 6e 73 65 4d 65 73  73 61 67 65 20 72 64 66   ponseMes sage rdf
0020  3a 61 62 6f 75 74 3d 22  23 43 52 32 34 22 3e 3c   :about=" #CR24"><
0030  72 64 66 3a 74 79 70 65  20 72 64 66 3a 72 65 73   rdf:type  rdf:res
0040  6f 75 72 63 65 3d 22 68  74 74 70 3a 2f 2f 77 77   ource="h ttp://ww
0050  77 2e 77 33 2e 6f 72 67  2f 32 30 30 32 2f 30 37   w.w3.org /2002/07
0060  2f 6f 77 6c 23 54 68 69  6e 67 22 2f 3e 3c 53 6f   /owl#Thi ng"/><So
0070  75 72 63 65 20 72 64 66  3a 72 65 73 6f 75 72 63   urce rdf :resourc
0080  65 3d 22 23 6a 75 75 75  75 22 2f 3e 3c 44 65 73   e="#juuu u"/><Des
0090  74 69 6e 61 74 69 6f 6e  20 72 64 66 3a 72 65 73   tination  rdf:res
00a0  6f 75 72 63 65 3d 22 23  44 65 66 61 75 6c 74 22   ource="# Default"
00b0  2f 3e 3c 4c 6f 73 74 4d  65 73 73 61 67 65 51 75   /><LostM essageQu
00c0  61 6e 74 69 74 79 20 72  64 66 3a 75 6e 73 69 67   antity r df:unsig
00d0  6e 65 64 4c 6f 6e 67 3d  22 32 32 30 20 32 32 31   nedLong= "220 221
00e0  20 32 32 32 20 32 32 33  20 32 32 34 20 32 32 35    222 223  224 225
00f0  20 32 32 36 20 32 32 37  20 32 32 38 20 32 32 39    226 227  228 229
0100  20 32 33 30 20 32 33 31  20 32 33 32 20 32 33 33    230 231  232 233
0110  20 32 33 34 20 32 33 35  20 32 33 36 20 32 33 37    234 235  236 237
0120  20 32 33 38 20 32 33 39  20 32 34 30 20 32 34 31    238 239  240 241
0130  20 32 34 32 20 32 34 33  20 32 34 34 20 32 34 35    242 243  244 245
0140  20 32 34 36 20 32 34 37  20 32 34 38 20 32 34 39    246 247  248 249
0150  20 32 35 30 20 32 35 31  20 32 35 32 20 32 35 33    250 251  252 253
0160  20 32 35 34 20 32 35 35  20 32 35 36 20 32 35 37    254 255  256 257
0170  20 32 35 38 20 32 35 39  20 32 36 30 20 32 36 31    258 259  260 261
0180  20 32 36 32 20 32 36 33  20 32 36 34 20 32 36 35    262 263  264 265
0190  20 32 36 36 20 32 36 37  20 32 36 38 20 32 36 39    266 267  268 269
01a0  20 32 37 30 20 32 37 31  20 32 37 32 20 32 37 33    270 271  272 273
01b0  20 32 37 34 20 32 37 35  20 32 37 36 20 32 37 37    274 275  276 277
01c0  20 32 37 38 20 32 37 39  20 32 38 30 20 32 38 31    278 279  280 281
01d0  22 2f 3e 3c 4e 75 6d 62  65 72 4d 65 73 73 61 67   "/><Numb erMessag
01e0  65 49 44 20 72 64 66 3a  75 6e 73 69 67 6e 65 64   eID rdf: unsigned
01f0  4c 6f 6e 67 3d 22 33 36  37 22 2f 3e 2e 2a 3f 3c   Long="36 7"/>.*?<
0200  2f 43 6f 6e 66 69 72 6d  61 74 69 6f 6e 52 65 73   /Confirm ationRes
0210  70 6f 6e 73 65 4d 65 73  73 61 67 65 3e            ponseMes sage>
```

(b) Confirmation response

Fig. 6. Snapshots of FINLAN confirmation messages

the field *LostMessageQuantity*. According to this capture, the packages from 220 to 281 were lost and only them were re-transmitted.

4 Conclusions

This work presented the Net-Ontology Layer, experimental results of its implementation and how it is possible to use ontology at the intermediate networks layers to understand and support different entities needs.

The results of using ontology to support the delivery guarantee need demonstrate an optimization of more than 30 percent of the packets sent in a file transfer, compared with the traditional TCP/IP protocols usage.

By the Net-Ontology use, it was demonstrated the possibility to substitute the traditional TCP/IP protocols used at the transport and network layers. This brings more semantic power for the Future Internet networks, as the network intermediate layers become able to better understand the entities needs.

Future Internet is being constructed with worldwide collaboration and is based on research and experimentation. Our previous work showed [17, 19] how FINLAN approach and the Title Model Ontology can work together with different efforts regarding the future, while the work presented details on how these proposals can come true.

As future works, it is expected to experiment the Net-Ontology implementation in different testbeds, such as OFELIA [11] and FIBRE (Future Internet testbeds/experimentation between BRazil and Europe)[2, 20]. In complement, it will be finished the actual working in progress to the experimentation using OpenFlow [10]. Also, experimental tests using workspaces for multicast aggregation [12] are being executed at OFELIA testbed.

The research and experimentation results show that we are facing a viable approach to introduce semantics at network lower layers, by contributing to bring richer and efficient services.

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