Towards an Ethical Analysis of the W3C Web Services Architecture Model

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Abstract— **This article explores the relevance of information ethics, the field that concerns itself with the study of ethical issues arising from the development and use of such technologies, for a specific information technology viz. Web services. In particular, the Web services architecture, as conceptualised by the W3C, is analysed using Floridi's theory of Information Ethics (IE). Firstly, it is shown that a technology such as Web services (acting as autonomous software agents and artificial agents with moral agency) should and could be subjected to a systematic ethical analysis that yields useful results. Secondly, the suitability and applicability of Floridi's ethical theory of IE is demonstrated by applying it to a complex system such as the Web services architecture. It is shown how the central notion of IE, viz. so-called levels of abstraction, supports major software systems design principles such as top-down design, structured analysis and design, and stepwise refinement and affords. This result is of particular significance since it opens up opportunities for the systematic and appropriate ethical analysis of any software system and may provide a general approach to "ethics by design".**

Keywords—Web services architecture model; Message Oriented Model; Floridi's theory of information ethics; level of abstraction; moral agent; moral patient

I. INTRODUCTION

The field of information security is diverse, including technical, managerial, legal, social and even philosophical issues. It may even be argued that large parts of the field of information security owe their existence to the challenges in information ethics and computing ethics that still need to be overcome. The boundaries between and the interweaving of information security and information ethics is a rich research domain. On the one hand we have the hard technical domain of security and on the other the softer, but much more elusive domain of ethics. As technology advances, the challenges in both domains are growing and information security management may be obliged to take cognisance of the benefits that information ethics offer in enhancing information security in software systems design and development. Web services are one such application that could create many ethical challenges in its design, deployment and use and was therefore selected for the purposes of this investigation.

By now Web services as a programming paradigm is well-established. Moreover, Web services constitute a key element in what has become known as "cloud computing" [6]. This reality emphasizes the significance of investigating Web services from a computing ethics point of view as more and more computing tasks of growing importance are performed by and entrusted to Web services. Moreover, the assumption that cyberspace, that is the space created by the Internet as well as those global networks constituted by ubiquitous computing technology and devices, is populated by both human and (autonomous) artificial/software agents, and that Web services may be viewed as artificial agents, affords us the opportunity of interrogating the ethical behaviour of Web services.

A Web service is a software system designed to support interoperable machine-to-machine interaction over a network [18]. Web services provide a framework for application-to-application interaction by supporting automated processes involving machine-to-machine cooperation and interaction [7], [17]. This method of interaction by autonomous software systems, on behalf of humans, creates many ethical issues which are worth studying. In particular, the ethical issues that arise in the design and use of Web services may be studied and analysed by means of, among others, its architectural models, which is the focus here.

The purpose of the paper is threefold: Firstly it is shown that a technology such as Web services (acting as autonomous software agents - artificial agents with moral agency) should and could be subjected to a systematic ethical analysis that yields useful results. Secondly, the suitability and applicability of Floridi's influential, but somewhat controversial (see, for example, [2, 12, 13]), rigorously developed ethical theory of IE is demonstrated when applied to a complex system. Finally, the significance of the findings of this analysis for the design and deployment of Web services that exhibit ethical behaviour is established. However, ethical issues that arise in, for instance, the implementation of Web services fall outside the scope of this paper.

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The Web services architecture (WSA) of the W3C provides a conceptual model and a context for understanding Web services and the relationships between the components of this model. The W3C distinguishes between four models in describing the WSA, viz. the Message Oriented Model (MOM), Resource Oriented Model (ROM), Service Oriented Model (SOM) and Policy Model (PM). Each model focuses on certain aspects of the Web service. The MOM deals with messages, message structure and message transport. The SOM is concerned with services provided by the Web service and actions needed to accomplish the service. The ROM focuses mainly on resources that exist and on relationships between resources and owners of the resources. Finally, the PM concerns the policies an agent has to adhere to while delivering services [18].

Each architectural model, as specified by W3C, is described in terms of concepts and relationships inherent to the model. The purpose of this paper is to investigate the suitability and applicability of 'Floridi's theory of Information Ethics (IE)' to the W3C WSA and the MOM in particular, in order to raise the ethical awareness in the design and use of Web services.

Our general approach may be briefly summarised as follows: IE employs the notion of the Level of Abstraction (LoA) to analyse a system. According to this theory a model of the system (architecture) can be constructed using various LoAs and their associated sub-models. The LoAs form the basis of the ethical analysis of the system under study. An important concept in IE is the agent-patient relationships in a model, a moral agent being an entity that is interactive, autonomous and adaptive and acts on another entity, usually referred to as the patient, for moral good or evil.

For the purposes of IE, the WSA is therefore viewed as a multi-level system. At the highest level a Web service facilitates the interaction between user (service requester/s) and service provider. The next level, referred to as the 'Meta Model of the Architecture', is in turn made up of the four models (MOM, SOM, ROM and PM) mentioned above. The focus then moves to the MOM with its sending, receiving and processing of messages as one of the main functions of a Web services application – activities in which ethical behaviour is essential. Various subsequent lower LoAs in the WSA are also identified. At each LoA and its associated sub-model relevant agent-patient relationships are analysed in terms of their moral responsibility and accountability.

The structure of the paper is as follows: The first section is devoted to a brief description of the WSA and the MOM in particular. This section is followed by a short discussion of computer ethics, ethical theories and Floridi's theory of IE that are of relevance in the ethical analysis of Web services. The third section concerns the application of Floridi's theory to various components of the MOM, including messages, sender and receiver agents, message transport, message exchange pattern, message correlation and message reliability. The discussion of the MOM is based on the notion of level of abstraction (LoA) and agent-patient relationships, as proposed by Floridi. The paper is concluded with suggestions for future work.

II. THE W3C WEB SERVICES ARCHITECTURE

Various models have been proposed to describe Web services architectures, many of which are based on three basic components viz. the service requester, the service provider and the service registry [1] – this is also the case in the W3C WSA of 2004. The latter WSA does not specify how Web services are implemented but describes the minimal characteristics and functionality that are common to all Web services, and a number of characteristics that are needed by many Web services [18].

The WSA under discussion can be layered into different levels based on its general view of stake holders at any specific level. The highest level provides an overview of a service user's engagement with a Web service as the service provider. At this level the architecture shows two main entities: the service requester entity (user) and the service provider entity (Web service). This highest model is illustrated in Fig. 2.

The second level is referred to as the *Meta Model of the Architecture* and is shown as a structured design diagram of the whole WSA. As expected it consists of four entities, viz. the MOM, SOM, ROM and PM [18], shown in Fig. 3. The MOM covers all aspects that relate to sending and receiving of messages and processing of messages, including the structure of messages, relationships between message senders and receivers and how messages are transmitted. The SOM focuses on those aspects that relate to service and action, in particular the relationship between agents and the service they provide and request, as well as actions or services that may be performed by an agent. The ROM concerns those aspects that relate to resources, independent of the role the resource plays in the context of Web services and include issues such as the ownership of resources and policies with resources. Aspects related to the service delivery policy are covered by the PM, which also describes related issues such as security and quality of service [18].

The third level consists of the four so-called *architectural models* [18] of which we only consider the MOM in this paper. At this level each model is explained schematically by showing each and every element of the model and all relationships between such elements. Each element is represented by a rectangle and arrows show the relationships between elements. It should be noted that the other three architectural models should also be subjected to a similar analysis (see section V).

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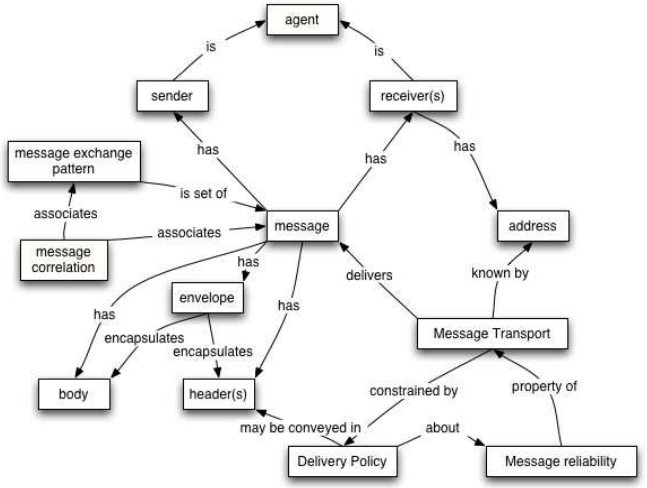

Figure 1. Message Oriented Model [18]

Fig. 1 shows the MOM and its elements and the relationships between them. The elements are briefly explained below. For extensive definitions, the interested reader is referred to [18].

Message: A message is the basic unit of data sent from one Web service to another. A message may be described using a service description language (for example, WSDL 2.0 [19]). A message has a sender and one or more recipients. The main parts of a message are its envelope, a set of zero or more headers, the message body and an identifier. The envelop serves to encapsulate the component parts of the message which are message body and message header. The header contains information about the message and facilitates modular processing. The body of the message contains the actual data resource. An identifier gives a unique name for the message which is normally realized by a URI.

Sender agent and receiver agent: A message sender is an agent that transmits a message to another agent and a message receiver is an agent that is intended to receive a message from the message sender. Although every message has a sender, the identity of the sender may not be available to others in the case of anonymous interactions. Messages may be passed through intermediaries that process aspects of the message. Both the message sender and recipient may or may not be aware of processing by such intermediaries. The ultimate message receiver is responsible for completing the processing of the message. Sometimes the receiver may receive messages which are not requested for, e.g. unsolicited mail. Both the sender and receiver agent could be a human, hardware, software or an (autonomous) software agent.

Message transport: The message transport is the mechanism used to deliver messages from the sender to the receiver. Examples of message transport include HTTP over TCP, SMTP and message oriented middleware [18]. It is the responsibility of the message transport to deliver message from the sender to the right receiver without being altered, copied or distorted. A message transport is constrained by various message delivery policies.

Message delivery policy: The message delivery policies are those that relate to the delivery of messages. The delivery policy constraints the message transport from delivering the message. A specific delivery policy is applicable to the combination of a particular message and a particular transport mechanism. A policy may originate from descriptions in the message, or built in the transport mechanism, or both. Examples of delivery policies include quality of service assurances, security assurances and recording of an audit of how message was delivered.

Message reliability: Message reliability is the degree of certainty that a message will be delivered from sender to the receiver on time without being copied, altered or distorted. The goal of message reliability is to reduce error and to provide sufficient information about the status of a message delivery. Such information enables a participating agent to make a compensating decision when errors or less than desired results occur. Message reliability may be realized by a combination of message acknowledgement and correlation and message transport mechanism.

Message exchange pattern: A message exchange pattern is a template that describes a generic pattern for the exchange of messages between agents. The patterns can be described by state machines that define the flow of messages and the correlation of messages. It describes relationships of multiple messages exchanged in conformance with the pattern, as well as the normal and abnormal termination of any message exchange conforming to the pattern and handling of faults that may arise. A message exchange pattern should have a unique identifier.

Message correlation: Message correlation is the association of a message with a context. Message correlation allows a message to be associated with a particular purpose or context. It may be realized by including message identifiers to enable messages to be identified. The message identifier is an identifier that allows a received message to be correlated with the originating request.

III. COMPUTER ETHICS AND ETHICAL THEORIES

Broadly speaking, computer ethics is the study of moral, legal, and social issues involving computing, information and communication technology. Founded in the early 1940s, computer ethics has acquired a robust and significant body of knowledge, which is characterised today by two very different views of the likely ethical relevance of computer technology. The more conservative perspective is that fundamental ethical theories will remain unaffected – that computer ethics issues are simply the same old ethics questions with a new twist – and consequently computer ethics as a distinct branch of applied philosophy will ultimately disappear. The second point of view sees computer technology as ethically revolutionary, requiring human beings to re-examine the foundations of ethics and the very definition of a human life [5].

A detailed discussion of various ethical theories that may be employed in an ethical analysis of Web services, such as disclosive computer ethics [2], the ethics of surrogate agents [14], just consequentialism [15], and machine ethics [16] falls outside the scope of this article. However, salient aspects of

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such theories will be mentioned where appropriate and relevant.

According to Moor artificial agents can be divided into implicit ethical agents, explicit ethical agents and full ethical agents. In implicit ethics software agents can only deployed in those areas where ethical decision making is not a questionable act. Therefore the agent will not do any unethical actions. In explicit ethics, codes have to be written to prevent agents from doing unethical actions. Finally in full ethics an agent can make ethical judgments and generally is competent to reasonably justify them [16].

Of particular significance are, however, Floridi's groundbreaking work on Information Ethics (IE) [10], a macro-ethical theory that may both serve as a foundation for computer ethics and guide our overall moral attitude towards the world [3], and Floridi and Sanders' levels of abstraction as a critical tool in specifying and analysing the ethical behaviour of information systems, including Web services [9]. This approach important for us since it supports major software systems design principles such as top-down design, structured analysis and design, and stepwise refinement. In the next section this approach is explicated.

A. Floridi's theory of Information ethics

Floridi and Sanders [8] argue that artificial agents (such as those found in Web services) could best be analysed based on the notion of Level of Abstraction (LoA). An '*information system may be described as a range of LoAs*' and ' a *LoA is determined by the way in which one chooses to describe, analyse and discuss a system and its content*' [8], [10]. Accordingly, the Web service architecture (of interest in this study) may be viewed at different LoAs. The architectural model at each LoA is made of many entities which could be classified as *moral agents* and *moral patients*. Moral agents are '*entities that can perform actions for good or evil*' and moral patients are '*entities that can be acted upon for good or evil*' [8].

In order to continue our discussion of Floridi's theory, it is important to define terms such as observables, interface, and LoA.

LoA: a finite but non-empty set of *observables*, which are expected to be the building blocks in a theory characterised by their very choice. LoAs can be nested, disjoined, or overlapping;

An *observable:* an interpreted typed variable, i.e., a typed variable together with a statement of what system under consideration it represents;

An *interface (also gradient* of *abstractions)*: a collection of LoAs. An interface can be used for analysing a system from varying points of view or at varying LoAs.

A detailed discussion of Floridi's *method of abstraction* and how it allows the analysis of system by means of models developed at specific gradients of abstractions may be found in [11]. Of particular interest to us is that IE allows us to interpret levels of abstractions *informationally*, that is we may think of systems as consisting of informational objects and processes where objects are agents and patients and processes are moral actions. This means that the *ethical analysis* of a system may be viewed as an informational model of moral action in which the moral agents and moral patients are objects in the system and moral actions are processes in the system. Our ethical analysis of the WSA will therefore centre on the identification of moral agents, patients and actions.

1) Moral agents

According to Floridi "a moral agent is an *interactive*, *autonomous* and *adaptable* transition system that can perform morally qualifiable actions" [10]. *Interactive* means the agent and its environment can act upon each other. *Autonomy* means an agent can change its state without being acted upon by its environment. This gives some sort of independence to the agent. And finally, *adaptable* means an agent can change its state by learning from the environment. "This property ensures that an agent might be viewed, at the given LoA, as learning its own mode of operation in a way which depends critically on its experience" [8,10].

Floridi states that "morally qualifiable actions are those that can cause moral good or evil" [10]. Morally qualifiable actions bring moral accountability and moral responsibility to an agent's actions.

2) Moral patients

In IE *patients* are entities that can be acted upon by another entity such as an agent for good or evil. According to IE "all entities, *qua* informational objects, have an intrinsic moral value, although possibly quite minimal and overridable, and hence they count as moral patients, subject to some equally minimal degree of moral respect understood as a *disinterested*, *appreciative* and *careful attention*" [10]. Floridi argues that "intangible or intellectual objects can have a minimal degree of moral value, no matter how humble, and so entitled to some respect" [10]. In terms of informational objects it means that a moral patient can rightly claim some kind of moral respect for the information that it represents from a moral agent no matter how minimal it is. "This means that the informational nature of an entity that may, in principle, act as a patient of a moral action, is the lowest threshold that constitutes its minimal intrinsic worth, which in turn may deserve to be respected by the agent" [10].

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3) What are the responsibilities of moral agents?

According to Floridi's theory a moral agent should have an "*ecopoietic* responsibilities towards the whole infosphere" [10]. The term *ecopoiesis* refers to "the morally-informed construction of the environment, based on an ecologically-oriented perspective" [10]. Based on this theory a moral agent is expected to have a global outlook that ensures that its action will not cause harm to itself and also others *informationally*. A moral agent must ensure that resources are sustainable for future generations also and an agent should be *accountable* and *responsible* for all actions [10].

IV. Application of Floridi's theory to Web services Architecture Model

Our main objective of this paper is to investigate the suitability of IE for an ethical analysis of the WSA by focussing on the MOM. The assumption is that similar analyses will be possible for the ROM, SOM and PM. For this purpose we identify five suitable LoAs, as well as associated agents and patients.

LoA1: Main elements at this LoA are *Requester Entity* and *Provider Entity*. This is the highest LoA where one is not particularly interested in the architecture of the Web services. This LoA will be analysing Web services based on users (service user) and service providers. This level will discuss issues such as privacy, intellectual property, filtering, censorship, the digital divide and service level contract between providers and requesters. *Moral agents* in this case are service providers and *patients* are service users or requesters. The *observables* at this level of abstraction are requester agents, provider agents and the messages that they exchange.

LoA2: At LoA2 Web services architecture is analysed based on its *Meta Model of the Architecture*. The Meta Model of the Architecture is made up of four models: *MOM*, *SOM*, *ROM* and *Policy Model*. The observables at this level are *Message*, *Action*/*Service*, *Resource* and *Policy*.

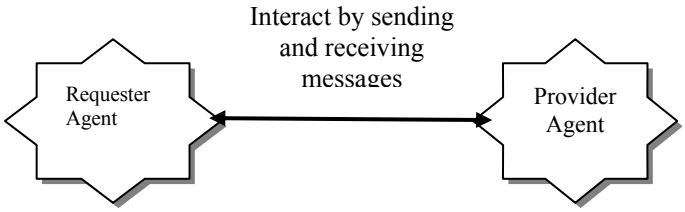

Figure 2. The general process of engaging a Web service [18]

LoA3 & LoA4: At this level Web services are analysed at each architectural model based on the structure given by W3C Working Group in 2004. We only consider the MOM here, which has at least two LoAs which may not be hierarchical, one related to the sending and receiving of messages and the other related to reliability, integrity and security of the message. The LoA3 observables are *message*, *message sender*, *message receiver* and *message transport* and those for LoA4 are *message delivery policy*, *message header*, *message exchange pattern*, *message correlation* and *message reliability*.

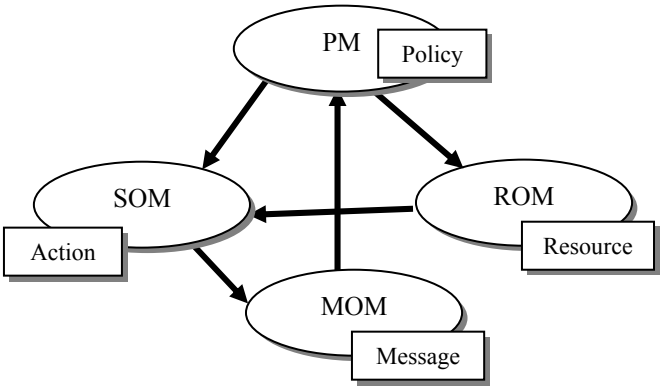

Figure 3. Meta Model of the Architecture [18]

The MOM (LoA4) is shown in Fig. 1.

LoA5: LoA5 may represent the implementation with a specific focus on coding. A detailed discussion of this part is outside the scope of this paper since implementation details do not form part of the WSA.

A. Analysis of Message Oriented Model

A message is the main focal point in MOM.

1) Relationship of message to other elements of the architecture

- A message has a message sender
- A message may be described using a service description language
- A message has one or more message recipients
- A message may have an identifier
- A message has a message body
- A message has zero or more message headers
- A message has a message envelope
- A message is delivered by a message transport system
- A message may have a delivery policy associated with it [18].

The MOM may be analysed at two levels: LoA3 and LoA4. LoA3 concerns the transfer of a message from sender to receiver through an appropriate transport mechanism while LoA4 looks at the reliability and integrity of the message being transferred. Agent-patient relationship where applicable will be used for this purpose.

An entity can only qualify for agenthood if it has the following properties: *interactivity*, *autonomy* and *adaptivity*. This classification has to be made at an appropriate LoA. Obviously aA human can be considered as a moral agent because human beings can *interact* with the environment, can make decisions without being influenced by others, i.e. *autonomous* and also can learn from previous experience, so it is *adaptive*. What about artificial (software) agents? We

illustrate this by means of an example of a web-bot which can be used for filtering unwanted e-mails from the Internet. A web-bot learns user's preferences, interact with incoming e-mails and filters out unwanted e-mails. In this case and at that LoA, web-bot can be considered as an agent because "bot adapts its behaviour to our preferences" [10]. At this LoA we don't have access to bot's code therefore we are not bothered whether or not bot uses code in order to exhibit its *observables*. The *observables* in this case are the inputs to the system, i.e. unfiltered mails and outputs from the system, i.e. filtered mail.

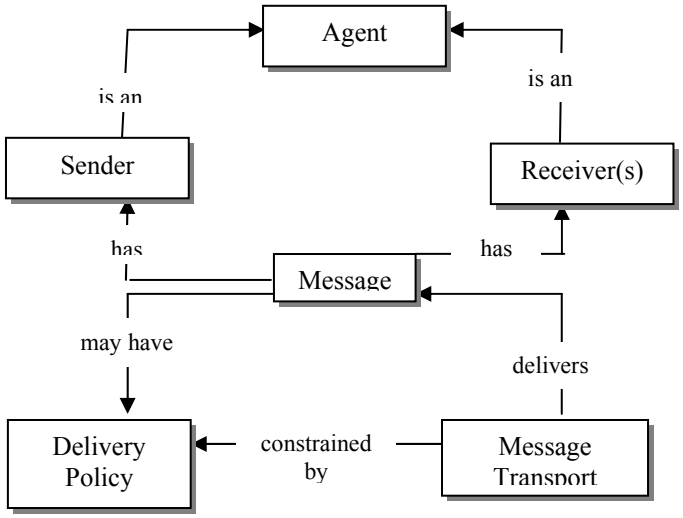

Figure 4. Model showing Message transport at LoA3 [18]

What elements/entities in the MOM qualify as moral agents and which not? Table 1 is based on observing the MOM, as proposed by the W3C working group and on their definitions and explanations of each architectural element.

B. Ethical analysis at LoA3

1) Message versus message sender

Both the message and message sender are objects in the "*infospere*". At this LoA, a sender could be considered as the agent and the message as the patient. The minimum respect the sender could give to a message, according to Floridi's "*ecopoietic* responsibilities", is to treat it as message and deliver it to its intended destination without being altered or copied.

TABLE I. ARCHITECTURAL ELEMENTS AND THEIR PROPERTIES BASED ON FLORIDI'S GUIDELINES. LOA AT THE ARCHITECTURAL MODEL LEVEL

LoA	Architectural element	Proeties constituting agenthood			Aget-patient relatioship
		Interactive	Autonomous	Adaptive	Agent/ Patient/ both/ none
LoA3	Message	Yes	No	No	Patient
	Message sender	Yes	Yes	Yes	Both
	Message receiver	Yes	Yes	Yes	Both
	Message transport	Yes	No	Yes	Both
LoA4	Message address	No	No	No	None
	Message delivery policy	Yes	No	Yes	Patient
	Message header	Yes	No	Yes	Patient
	Message exchange pattern	Yes	No	Yes	None
	Message correlation	Yes	No	Yes	Patient

It is possible that the contents of the message are intercepted by unauthorised entities during the course of transmission. The message can be copied, altered, used and disseminated without the consent of the stakeholders. This violates the privacy of an individual or organisation and can cause unnecessary harm. Who will be held accountable in this situation? It is not easy to find an answer to this question because there are many players involved in the transmission of the message. Let use analyse this at LoA4.

A message has to have an address in order for message transport to deliver a message appropriately. The form of the address information depends on the particular message transport. The precise method that a sender uses to convey address information will also depend on the transport mechanism used [18].

There are various security issues that may arise, collectively referred to as the "message level security threats" that are applicable to both message and message address. Some of these threats are message alteration, spoofing, denial of service and replay attack [18].

Is the sender responsible for these attacks? In a way it is, since it is the responsibility of the sender to ensure the security and integrity of the message. However, the sender can only achieve this with the help of other entities such as message transport.

The message transport is the actual mechanism used to deliver messages. It is the responsibility of the message transport to deliver a message from a sender to one or more recipients by ensuring the integrity and the security of the message [18].

The question now is: does the sender have any control over the message transport? Closely observing the MOM, shows that the sender has no control over the message transport. Although message reliability is a property of message transport, the sender cannot implement it. The sender has no agent - patient relationship with message transport. Therefore, in our view, the sender could not be held responsible for the reliability and integrity of the message transport - the MOM does not allow the sender to have any control over the message transport. To make the sender accountable, the sender should have been given the right to have access to a reliable message transport. Still, the sender has the shared responsibility to ensure that the message has been delivered to the intended recipient on time and the integrity of the message is not

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compromised. Therefore to ensure the reliability and integrity of the message the message transport should be reliable and contents of the message have to be secured.

2) Message versus message receiver

Similar to the message sender, a message receiver could be human, hardware, software or a software agent that is intended to receive a message from the sender. A receiver agent is also a requester agent that wishes to *interact* with a sender or provider agent to receive a response for a request. It is obvious that the receiver has to interact with the infosphere to receive a message. Therefore there is interaction with the environment. What type of relationship exists between a message and receiver and between sender and receiver? It is possible that the receiver may undergo a state transition upon the receipt of the message. Therefore a receiver can be considered as a patient and the message can be considered as an agent at this LoA. While in our earlier analysis we stated that a message does not qualify to be an agent based (see Floridi's guidelines), at this LoA a message acts as an agent that is able to initiate a state transition in receiver.

Since a message is sent by a sender agent, it is the sender that initiates change in state transition in a receiver. Thus, there exists an agent-patient relationship between the sender and the receiver. At this LoA the sender is the moral agent and the receiver is the patient. Therefore it is the responsibility of the sender to ensure the reliability and integrity of the message. However, we stated earlier that the sender cannot guarantee the reliability and integrity of the message because of various other factors that exist in the infospere where both sender and receiver are present. A receiver is also a requester, this means a receiver may send a message to the sender requesting for a service. At this LoA the receiver becomes the sender and the sender becomes receiver. Therefore a sender and the receiver can both act as an agent and patient at different LoAs.

3) Message sender versus message receiver

In the MOM both the sender and the receiver have significant moral responsibility due to their positions as both agents and patients at different LoAs. A receiver has an address which is known to the message transport [18]. It is the responsibility of the message transport to ensure that the receiver receives accurate and reliable message on time. As mentioned earlier, the integrity and security of the message delivered to the receiver can be compromised because of the various other factors in routing of the message. Although the sender and the receiver have an agent-patient relationship, the sender cannot do much about it because both the sender and receiver are at the mercy of message transport for the reliability and the integrity of the message. Therefore, there exists an agent-patient relationship between the message transport and the receiver where the message transport is the agent and the message receiver is the patient. Similarly, the sender is the moral agent and the message transport is the patient though there is no direct link between the two in MOM.

4) Message versus message transport

A message transport is a mechanism in the WSA for delivering the message from a sender to one or more recipients [18]. According to the MOM architecture, message reliability is one of the properties of the message transport. At this LoA message transport can be considered as the agent and message as the patient. The integrity, security and reliability of the message are dependent on the ability of the message transport to deliver the message on time without being altered and copied. But, the message transport is constrained by the delivery policy. Therefore, at this LoA the message transport is a patient and delivery policy an agent. So, it is a chain reaction where the delivery policy constrains the delivery mechanism, i.e. message transport and message transport constrain the reliability and integrity of the message. Therefore, message transport has to be secured, based on the delivery policy to ensure the security, reliability and integrity of the message. The delivery policy should also be interactive and adaptive, based on the sensitivity of the message.

C. Ethical Analysis at LoA4

At this LoA the architecture is analysed by considering how message reliability is related to the message delivery policy, message exchange pattern and message correlation.

Let us consider how message reliability, message exchange pattern, message correlation and message delivery policies are related. Message reliability may be realised by a combination of message acknowledgement and message correlation. A message exchange pattern may realise message correlation. Message reliability may also be realised by a message transport mechanism. A message transport is constrained by various message delivery policies. (The statement "concept X is realised as Y" denotes that the concept X is implemented using Y) [18].

We now analyse the agent-patient relationship between these entities. Message correlation is the association of a message with a context. At this LoA message correlation is an agent and message reliability is a patient. In any form of communication, it is important to be able to determine that that an actual message that has been received is the expected message [18]. Therefore it is the responsibility of the message correlation to ensure the reliability of the message.

A message exchange pattern describes a generic pattern for the exchange of messages between sender and receiver [18]. At LoA4 the message exchange pattern can be considered as an agent and message correlation can be considered as patient. Therefore it is the responsibility of the message exchange pattern to correlate message appropriately so that a requester agent can match the reply with the request. This is particularly important when multiple replies are possible for a request in a distributed application such as Web services. This in turn will ensure the reliability of the message.

The relationship between message reliability, message transport and message delivery policy has already been discussed earlier at LoA3.

We conclude that the identification of moral agents, patients and actions allows us to focus on aspects of a system that are of ethical significance. Addressing and resolving each such issues may require a variety of specific ethical approaches, for example, disclosive computer ethics [2], the ethics of surrogate agents [14], just consequentialism [15],

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machine ethics [16], deontic logics for formalising ethical codes [4], etc.

V. Conclusion and Future Work

Firstly, it was shown that that a technology such as Web services (acting as autonomous software agents and artificial agents with moral agency) should and could be subjected to a systematic ethical analysis that yields useful results. Secondly, the suitability and applicability of Floridi's ethical theory of IE was demonstrated by applying it to a complex system, in particular, the WSA. Finally, the significance of the findings of this analysis for the design and deployment of Web services that exhibit ethical behaviour was established.

By using Floridi's theory it was possible to divide the WSA into different models based on the LoA at each level. It was also possible to categorise elements in the MOM as moral agents or moral patients based on their roles in the model. However, Floridi's theory could not be fully applied in some instances because in some entities do not fully comply with the guidelines for agenthood - an entity can only qualify as an agent, if it is *interactive*, *autonomous* and *adaptive* [10]. In the MOM only the sender agent and receiver agent strictly qualify for agenthood based on Floridi's guidelines. Moreover, care should be taken in characterising an entity as an agent or patient. In some cases it may not be possible to categorise an entity either as an agent or as a patient.

Finally it was is shown how the pivotal notion of IE, viz. so-called levels of abstraction, supports major software systems design principles such as top-down design, structured analysis and design, and stepwise refinement and affords. This result is of particular significance since it opens up opportunities for the systematic and appropriate ethical analysis of any software system and may provide software systems designers and developers with a useful applicable general approach to "ethics by design".

Future work includes, among others, (i) the investigation into the suitability and application of a variety of microethics theories for use together with Floridi's (macroethics) theory in order to assist both the designers and users of complex software systems in taking appropriate steps while designing or using such systems; and (ii) research on extending the present approach and analysis to general complex software systems and information technology. It is hoped that by doing so the integrity of the infosphere will be protected to the benefit of all.

VI. References

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