International Interoperability Through Unified Universal HL7 v3 Green Messaging

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***Abstract* - *Health Level Seven* (HL7) is the most popular, global healthcare standard in use today. Introduced in 1987 by the *HL7 International Inc.*, the current version 3 has been promoting *Semantic Interoperability* (SI) which is two or more computer systems exchanging valued healthcare information with *homogenous understanding*. Thus, efficient implementation for optimal, high-end *SI* entails the abridgement of verbose v3 *Message* paradigm representations, whilst strictly maintaining their semantic *nuance* and *flavour*. The resulting *economised* structures termed *Green Messages*, have to be truly universally overarching, affording and facilitating *International Interoperability*. Aligned with this core *Greening* requirement is the demand for secured, efficacious exchange of data and information "*in the wire*", promoting overall efficiency.**

This paper outlines conclusive research on all *greening fronts*, and underscores sound methodologies to realize true *International Interoperability* and *superlative* efficiency, as *appraised* by the ten, archaic *System Performance Indicators* (SPIs) used.

***Keywords* – International Interoperability, Semantic Map, Semantic Blending.**

I. INTRODUCTION

The concept of *Green Clinical Document Architecture* (*CDA*), the *Document* paradigm in the HL7 standard, has been the focus of many recent fora and literature [1]. We however believe that a conceptual extension to the *Messages* realm is indeed possible and more profitable, and is the driving requirement for true *International Interoperability*. *Mushrooming pockets* of *green CDA* environments operate well within national boundaries but subvert *International Interoperability*. The obvious parsing and interpretation issues arising from exchanging country-specific *green CDA artifacts*, sabotage universal *semantic interoperability*. This pivotal research examined this *anomaly* and its *deleterious* effects on system performance. We propose the *Unified Universal Green Messaging* solution as the panacea for these ills; *messages* being the mobile element in the *tri-paradigmic* HL7 standard.

This paper addresses the research question "How to achieve true International Interoperability and performance augmentation through enhanced HL7 structure and processes". The proposed *greening* solution encompasses figments of the *International Organization for Standardization's* (ISO) *Open Systems Interconnection* (OSI) *Transport* layer 4 and *Session* layer 5, in redefining and enhancing current *HL7-TCP/IP* interactions, in addition to pruning v3 message structures(OSI layer 7). Related recent research conducted by Li et al [12] enunciates *Semiotic Interoperability* which is *signs-and-symbols-oriented interoperability* for systems integration. Six levels of *sequentially-integratable* interoperability were defined, in bottom-to-top order *Physical*, *Empiric*, *Syntactic*, *Semantic*, *Pragmatic*, and *Social*. The proposed bi-threaded *greening* approach presented herein is kindred, seamlessly overlapping to provide a pragmatic, practical, and overarching *interoperability* solution.

The rest of this paper is organized as follows. Section II presents the *Enhanced Green Messaging* approach for *International Interoperability*. Section III improved on the current *HL7-TCP/IP* functionality, and Section IV winds up with the Conclusion section.

II. ENHANCED GREEN MESSAGING FOR INTERNATIONAL INTEROPERABILITY

All HL7 v3 messages can be broadly classified into three, according to [5] :

i. Messages with *no payload*, with only 2 wrappers, *Transmission* and *Control Act Event*, eg., ACK, Trigger Event Requests.

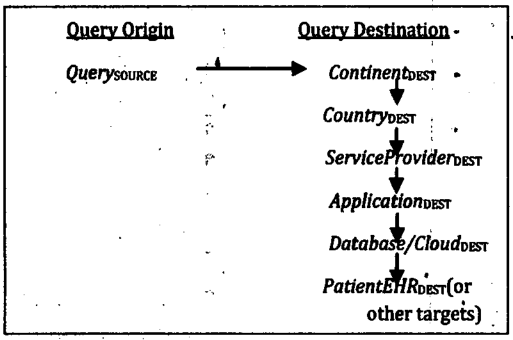
ii. Messages of *Query/Response Interaction Type* consisting of the 2 wrappers, and the *Query by Parameter/Query Response* body.

25/74

iii. Messages with significant domain content, eg., the *Document Notification Interaction Type* consisting of the 2 wrappers, and the Document body.

Due to the inordinate *length* and *loquacity* of the proposed formal *Greening* methodology, we will present the *necessary and sufficient gist* of the process applied to the *Transmission Wrapper*. Indeed this methodology can be extrapolated to cover all v3 message segments. *International Interoperability* requires the universal referencing of *artifacts*, eg., *Universal User IDs*(UUIDs) and *Object IDs* (OIDs) both aid universal reference, as indicated by the *probe sequence* shown in Fig.1.

Fig.1. HL7 v3 Message - Query Probe Sequence



Given this model, we propose a locally-maintained *UUID* for *query-target* reference, of the given form.

$\{UUID \equiv [\text{Continent}_{DEST}, \text{Country}_{DEST}, \text{SP}_{DEST}, \text{Application}_{DEST}, \text{DB-Cloud}_{DEST}, \text{PatientEHR}_{DEST}]\}$

A. Merits of Universal UID Maintained Locally

i) The *UUID* is easy to form given knowledge of the network *tiering* and *clustering*.

ii) Creation and maintenance of the *UUID* elements is done efficaciously locally, but is of universal (interoperability) value when required. Contrast with the heavy tab on system resources if OIDs have to be maintained at local and global OID registries as well.

iii)Easy automation possible once the network *tiering* and *clustering* is pre-defined in the application. *UUIDs* can be system generated.

In case *OIDs* are used to preserve the current uniformity in implementations,then their construction is similar. As such, we have empirically [9],

$\{OID \equiv 1.999999_{C1}.999999_{C2}.999999_{SP}.999999_{A}.999999_{DB\text{-}C}.999999_{P}\}$ where

C1–*Continent*, C2-*Country*, SP–*Service Provider*, A-*Application*, DB-C – *Database-Cloud*, and P-*Patient*.

B. Message Greening Process

The following table starts with a *sample* fully-fledged v3 Transmission Wrapper message segment and converts it to the proposed *Universal Green* version. Token usage explanations and the original v3 message structure were derived from **[2]**, **[3]**, and **[4]**. The *greened* target message contains "*only the most pertinent*" v3 source message elements needed for *qualitative content communication*, ie., those the specified interaction "*cannot do without*". All other superfluous and ancillary source message elements are disregarded in the *greening* transformation.

TABLE. 1 *Greening* Conversion

No.	Fully-Fledged Message Token	Related *Green* Token	Semantics Change
	Transmission Wrapper		
1	XML Header disregarded	same	None
2	Id root	Id root	None
3	extension	extension	None
4	creationTime	Not Used *Greened* out here, used later.	None
5	versionCode	Not Used *Greened* out	None
6	InteractionId root	interactionId root	None
7	extension	extension	None
8	processingCode	Not Used *Greened* Out	None
9	Receiver typeCode = "RCV"	Receiver typeCode = "RCV"	None
10	device classCode= "DEV"	Not Used *Greened* Out	None
11	determinerCode = "INSTANCE"	Not Used *Greened* Out	None
12	id extension	Not Used *Greened* Out.	None
13	root	Not Used *Greened* Out	None
14	asLocatedEntity classCode = "LOCE"	Not Used *Greened* Out	None
15	Location classCode = "PLC"	Not Used *Greened* Out	None
16	determinerCode = "INSTANCE"	Not Used *Greened* Out	None
17	locationDetails	locationDetails	None
18	id root	id root	None
19	extension	extension	None
20	name	name	None
21	existence Time	Replaced by "*Receiver Application Time*", - modified	None
22	Not Used	"*Receiver System Time*" – new	None
23	telecom Value	telecom Value	None
Same	***as above For***	***Sender***	
24	Acknowledgement "ACK"	Acknowledgement "ACK" sent back to Sender..	None

		The original message details kept for reference. Indicates (OK).	
25	Not Used	ACK sent "System Time"- new	None
26	Not Used	ACK sent "Application Time" - new	None
Same for	ACK received	System and application time - new	None

C. Semantic Equivalence of Source and Target (Green) Messages

This is proved using the technique *Semantic Map Trimming and Blending*. The *Extended Markup Language* (XML) source message (M_S) and the target *Green* message (M_G) are compared and the former is shaped and trimmed to fit the latter, and *Complete Blending* is validated. This preserves the original semantics of M_S during the *greening* transformation to M_G. Let *Semantic Map* $SM(M_S)$ be set denoting the *XML* source message and *Semantic Map* $SM(M_G)$ be the set denoting the target *Green* message (M_G) representations.

Proof:
Relation $G : SM(M_S) \rightarrow SM(M_G)$ is a complete transformation with *Semantic Preservation*. (Note : A relation is said to be *Complete* if it is *Non-Injective*, *Surjective*, and there are no unmapped elements left in the source and target sets). By definition,

***Non-Injection* of G** : $\nexists$ 1:1 mapping G of elements from domain M_S to codomain M_G
$\forall m_{Si} \in M_S \wedge \forall m_{Gj} \in M_G \wedge i \in N \wedge j \in N$
$\Rightarrow 1 : n \wedge n : 1$ mappings are also possible

***Surjection* of G** : $\forall m_{Gj} \in M_G \; \exists m_{Si} \in M_S$ such that $G(m_{Si}) = m_{Gj}$, $i \in N \wedge j \in N$
$\Rightarrow G : M_S \rightarrow M_G$ is an "*onto*" relationship.

The *empirical* representations of the semantic Maps of M_S *and* M_G are given below. Since the XML *Header* section statements (*topLevel, namespace Declaration*) and any *xmlComments* pass through *untampered*, the initial source M_S set can be trimmed to the actual *green-mappable* set under G. This is akin to *shaping and trimming* the *Semantic Map*(M_S) to fit the *Semantic Map*(M_G) for complete blending.

Trimmed SM(M_S) Set ⟶ (1)

m_{S1} : *xmlElement(rootElement)*$^{\{1\}}$
m_{S2}: *xmlElement*(openingTag, closingTag)*
m_{S3}: *xmlElement*(openingTag, elementValue, closingTag)*
m_{S4}:*xmlElement*(openingTag,notUsedElement, closingTag)*
m_{S5}:*xmlElement*(openingTag,(labelName,labelValue)*$^{+}$, *closingTag)*
m_{S6}:*xmlElement*(openingTag,(attributeName,attributeValue)*$^{+}$, *closingTag)*
m_{S7}:*xmlElement*(openingTag,* m_{S2}^{+}, m_{S3}^{+}, m_{S4}^{+}, m_{S5}^{+}, m_{S6}^{+} *closingTag)*

The $SM(M_G)$ set is given below ⟶ (2)

m_{G1} : *xmlElement(rootElement)*$^{\{1\}}$
m_{G2}: *xmlElement*(openingTag, closingTag)*
m_{G3}: *xmlElement*(openingTag, elementValue, closingTag)*
m_{G4}:*xmlElement*(openingTag,notUsedElement,closingTag)*
m_{G5}:*xmlElement*(openingTag,(labelName,labelValue)*$^{+}$, *closingTag)*
m_{G6}:*xmlElement*(openingTag,(attributeName,attributeValue)*$^{+}$, *closingTag)*
m_{G7}: *xmlElement*(openingTag,*m_{G2}^{+},m_{G3}^{+}, m_{G4}^{+},m_{G5}^{+}, m_{G6}^{+}*closingTag)*

From Table 1, (1), and (2), it can be established that

G is Non-Injective : $\nexists$ 1:1 mapping G of elements from domain M_S to codomain M_G
$\forall m_{Si} \in M_S \wedge \forall m_{Gi} \in M_G \wedge i \in N \wedge j \in N$
$\Rightarrow 1 : n \wedge n : 1$ mappings are also possible.

G is Surjective : $\forall m_{Gi} \in M_G \; \exists m_{Si} \in M_S$ such that $G(m_{Si}) = m_{Gi}$
$\Rightarrow G : M_S \rightarrow M_G$ is an "*onto*" relationship.

Now to prove that every member of M_S is acted upon by and transformed by G

$\Rightarrow \forall \; m_{Si} \in M_S, \; G: M_S \rightarrow M_G$ is True (3)

Suppose this is NOT True

$\Rightarrow \exists \; m_{Si} \in M_S, \; G: M_S \not\rightarrow M_G$ ▼
$\Rightarrow G(m_{Si}) = \phi$ (null set) $\vee \; G(m_{Si}) = \infty$

as any other valid target *green* token m_{Gi} would be such that $m_{Gi} \in M_G$

$\Rightarrow \#$ as $\phi, \infty \notin M_G$ by definition of M_G (target *green* M_G set)
$\Rightarrow \forall m_{Si} \in M_S, \; G: M_S \rightarrow M_G$ is True as in (3)

Thus, *every element of source XML message M_S is acted upon by and transformed by G*, and
$G: M_S \rightarrow M_G$ - is an "*onto*" relationship (*Surjective*)
Thus, G. is a *Complete Transformation* (*relation*). No unmapped elements are left in M_S or M_G.

The *Semantic Map Trimming and Blending* proof is completed by showing that the source v3 XML message *precedence* and *nested ordering* is preserved during the *green* transformation
$G : M_S \rightarrow M_G$. As the root *XML* element is always at position 1 of the source v3 message token stream of *green-mappable* elements in any interaction, it is left out. The other six source v3 *XML* message element types can appear in any permutation in the source message M_S a multiple number of times. eg.,

G (m_{S2}, m_{S3}, m_{S5}, m_{S4}, m_{S2}, m_{S6}, ... *n* times),
{$n \in N$ is the no. of mappable elements and $m_{Si} \in M_S$ }
$\Rightarrow m_{G3}, m_{G4}, m_{G5}, m_{G3}, m_{G3}$, ...n times ⟶ (4)

Each $G(m_{Si}) \rightarrow m_{Gj}$ where $i,j \in N$ transforms exactly one *XML* source message token to the target *green* message M_G token. By definition G is *strict* and *ordered* and thus target *green* message tokens are generated in sequence preserving the precedence and nested order of the source v3 *XML* message.

The proof by Mathematical Induction follows.

By definition, (4) is always true.

Base Case : n=1
Then $G\ (m_{S2}) \Rightarrow m_{G3}$ which is true.

Inductive Step
Assume it is true for n also
ie., $G\ (m_{S2}, m_{S3}, m_{S5}, m_{S4}, m_{S2}, m_{S6}, \ldots$ n times), $\{n \in N$ is the no. of mappable elements and $m_{Si} \in M_S\}$
$\Rightarrow m_{G3}, m_{G4}, m_{G5}, m_{G3}, m_{G3}, \ldots\ldots$ n times
When $n = n+1$
$\Rightarrow G\ (m_{S2}, m_{S3}, m_{S5}, m_{S4}, m_{S2}, m_{S6}, \ldots n$ times) $\cup\ G\ (m_{Si})$
$m_{Si} \in M_S\ \{i = 2,3,4,5,6,7\}$
$\Rightarrow G\ (m_{S2}, m_{S3}, m_{S5}, m_{S4}, m_{S2}, m_{S6} \ldots, m_{Si}$ $n+1$ times) (Union Theory of Sets)
Considering the target *green* M_G (RHS) of Transformation G, we have
$\Rightarrow \{m_{G3}, m_{G4}, m_{G5}, m_{G3}, m_{G3}, \ldots\ldots, m_{Gi}$ $n+1$ times}
Suppose G did not append m_{Gi} at the tail of set M_G at the $(n+1)^{th}$ position then m_{Gi} should have been inserted at any one of the positions 1 through n. Suppose m_{Gi} was inserted at position 1. Since m_{Gi} is arbitrary let $m_{Gi} = m_{G2}$
Then we have
$G\ (m_{S2}, m_{S3}, m_{S5}, m_{S4}, m_{S2}, m_{S6}, \ldots\ldots, m_{Si}$ n+1 times)
$\Rightarrow (m_{G2}, m_{G3}, m_{G4}, m_{G5}, m_{G3}, \ldots$ $n+1$ times) which gives
$G\ (m_{S2}) \Rightarrow m_{G2}$ #
(as by definition of G, $G\ (m_{S2}) \Rightarrow m_{G3}$) .

Contradictions can be formulated for all *other possible* m_{Gi} positions 1 through n. Therefore the $(n+1)^{th}$ target *green* message token generated by
$G\ (m_{S2}, m_{S3}, m_{S5}, m_{S4}, \ldots\ldots m_{Si}, \ldots$ $n+1$ times) is attached at the tail of $M_G \Rightarrow (m_{G3}, m_{G4}, m_{G5}, m_{G2} \ldots n+1$ times) thus preserving the original source v3 *XML* message precedence and nesting order. Hence, if the strict precedence and order preservation by $G : M_S \longrightarrow M_G$ is true for n elements, it is true for n + 1 elements as well. Therefore by the theory of Mathematical Induction, the proof is true for all positive natural numbers $n \in N$ *QED*
Thus, $G: M_S \longrightarrow M_G$ is *semantically complete.*

III. ENHANCED HL7 UNIFIED UNIVERSAL GREEN MESSAGES – *TCP/IP* FUNCTIONALITY

Our *Green* approach of *enhancement* is also applicable to "*in the wire*" improvement of *TCP/IP – HL7* interactions with a view to achieving enhanced *International Interoperability* and also significantly *augmenting* the ten system *PI* statistics. The proposed *Green TCP/IP– HL7 Interaction process* is illustrated below.

D. Proposed Green TCP/IP–HL7Interactions

i) Two levels of operational hierarchy are defined, namely, *Application* and *System*. Application level processes handle activities such as syntactic parsing and preprocessing and RIM reference. System level processes generate or internalize communication exchanges of messaging, and *payload-annotation.* The current TCP/IP-HL7 interactions define three hierarchical levels, namely *Application*, *Accept*, and *Commit* levels [7].

ii) A *Syntactic Preprocessor/Parser* (*SPP*) is situated at the extremities of each line of communication, connected to the *RIM* via a *RIM-adaptor*. It performs RIM-referencing, and checks the syntactic correctness of incoming/outgoing messages.

iii)ONLY a single message thread is used for the entire communication; the entire operation works on a single message acknowledgement (ACK) (payload-less) or a single response message (with payload), per source message. In the case of the former, since the single ACK *reciprocates* the inbound source message, it is created at the system level, annotates the stripped off inbound message's green and yellow tags(carrying the inbound message's *tag reference numbers*) at the outbound system and application levels respectively, along with the outbound message creation and message pass-through timestamps at the respective levels. In the case of a response message with domain-content(payload), the outgoing payload is *scrambled* at system level and the *Trigger Event Control Wrapper* and *Transmission Wrapper* respectively annotated at the application level.

iv) Each source message is time-stamped and colour-tagged as shown below :

Message generate time-stamp + colour tag (green) – *System level*

Message pass-through time stamp + colour tag(yellow) - *Application Level*

Both colour tags possess individual, unique *Tag Reference Numbers* which help manage the bi-tiered flow-control of messages affording finer-granularity.

On message receipt at destination the following processing is conducted.

Stamp Message Received Time + strip-off colour tag(yellow) - *Application Level*

Stamp Message Commit Time + strip-off colour tag (green) – *System level*

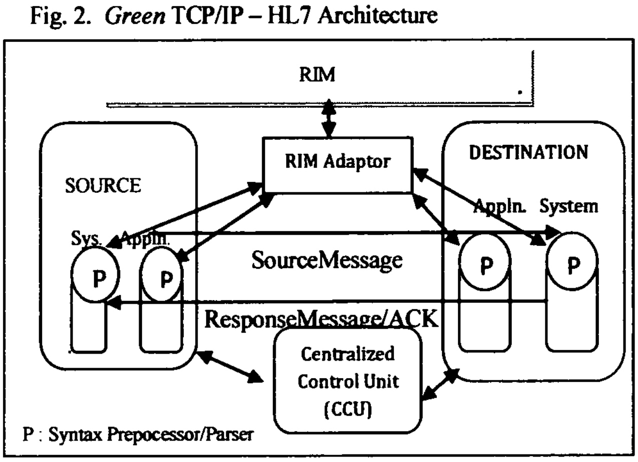
Both stripped-off colour tags would still possess the original, individual, unique *Tag Reference Numbers* which help manage the bi-tiered flow-control of messages.

v) Bi-level (Application and System) RIM references occur during message parsing thorough the RIM adaptor at source and destination.

vi) The entire operation is free from the *Negative Acknowledgement* or NAK payload-less response message, usually returned on error conditions. The proposed *Green TCP/IP-HL7* interaction process works on the *timeout* principle. On message dispatch, if the *cycle time* or *turnaround time* exceeds a threshold, a *timeout* is declared, the sent message is considered *lost*, and a new copy dispatched with new timings and colour tags (with reference numbers). The *Central Control Unit* (CCU) which oversees all network interactions, records errors on receipt at all destinations. Hence, the *sender* checks the status (ie, *lost, error*) of the previously sent message with the CCU (lookup-table), before dispatching new copy. The idea is to reduce superfluous network traffic to a bare minimum. The same is true for response messages. In the case of successive timeouts reaching a *threshold*, a "*line down*" situation is declared and rectification sought.

vii) When a new message copy is dispatched, the *Central Control Unit* (CCU) deactivates and removes any redundant, residual, communication such as *timed-out* messages or responses stuck *midstream*, due to line issues. This proposed solution preserves and maintains a "*clean*" line enabling speedy, efficient communication and interoperability.

Fig. 2. *Green* TCP/IP – HL7 Architecture



viii) The proposed *Green* HL7 v3 messaging protocol is strictly paired. Each outbound message would receive an inbound response (either a message or an ACK) which completes the "*handshake*"; no other ancillary communication surrounding the *core* interaction exists. If source message is lost, on timeout, a new copy could be sent.

The following table compares the HL7 v3 *Green Messaging* with its conventional counterpart. The regular *TCP/IP-HL7* interactions and methodology were obtained from **[6]**.

TABLE 2: TCP/IP-HL7 vs Green - Enhancements

Segment No.	**TCP/IP-HL7 Segment**	**Green TCP/IP-HL7 Segment**	**Extra Work Done in Regular TCP/IP – HL7 Segment**
1	**Immediate ACK** Message received at Application level, syntax is validated, ACK/ NAK is returned	Message received at Application level, P checks syntax reference to RIM.	Make/Send top level ACK/NAK is ω
2	Message received at Accept Level, validated.	Message passes through.	Extra WD in regular TCP/IP-HL7 : 1) validate Message at Accept Level = δ 2)Make/Send ACK/ NAK = ω
3	Message received at Commit Level	Message received at system level	No change.
4	Check Exceptions. If data is incomplete, then re-read.	Check Exceptions. If data is incomplete, then re-read.	No change.
5	If no exceptions, do third validation at commit level. Then send ACK/NAK.	If no exceptions, do second validation at system level. If OK send ACK to source	WD in regular TCP/IP-HL7 : 1)Make/Send ACK/ NAK = ω ⇒ Make/Send ACK only = ω/2 (assuming equi-probability)
6	Same for a payload–ridden V3 message response.	Same for a payload–ridden V3 message response.	No Change
		Net Extra WD for Immediate ACK	ω + δ + ω + ω/2 ⇒ (5ω/2+ δ) units
7	**Deferred ACK** Message received at Application level, syntax is validated, ACK/ NAK is returned.	Message received at Application level, P checks syntax correctness with reference to RIM.	Extra Work Done (WD) in regular TCP/IP-HL7 : Make/Send top level ACK/NAK is ω
8	If enabled, sequence numbering checked for validity. If valid send ACK and pass through, or send NAK	Bi-tiered sequence checked at both application and system levels using the yellow and green colour tags.	Make/Send top level ACK/NAK is ω
9	Check Exceptions	Check Exceptions	No change.

29/74

	If data is incomplete, then re-read.	If data is incomplete, then re-read.	
10	If no exceptions, do validation at commit level. Then send commit-level ACK/NAK to source based on outcome.	If no exceptions, do second validation at system level. If success the send single system-level ACK to source.	Extra WD by regular TCP/IP solution $\Rightarrow \omega/2$
11	Same for a payload–ridden V3 message response.	Same for a payload–ridden V3 message response.	No Change
		Net Extra WD for Deferred ACK	$\omega + \omega + \omega/2$ $\Rightarrow (5\omega/2)$units

E. Analysis

The above *empirical* reasoning proves that the efficiency in work done(*Economy in Work Done-EWD*) of the Green solution far exceeds that of the regular *TCP/IP–HL7* counterpart.

***EWD* by *Green* TCP/IP-HL7 for Immediate ACK**

Processing = $\Delta h_i = (5\omega/2 + \delta)$ units

Per Round Trip = 2 x $\Delta h_i = (5\omega + 2\delta)$ units

***EWD* by *Green* TCP/IP-HL7 for Deferred ACK**

Processing = $\Delta h_d = (5\omega/2)$ units

Per Round Trip = 2 x $\Delta h_d = 5\omega$ units, where

ω: work done to make/send a single ACK or NAK.

δ: work done for a single RIM-based message syntax validation. This is so for both payload (domain-content) or is payload-less (like an acknowledgement or inquiry) messages.

Economy in Work Done ΔE by *Green* interactions in *ideal* conditions for a cloud of m messages

ΔE_I (per round trip) = $m(5\omega + 2\delta)$ units

ΔE_D (per round trip) = $m5\omega$ units

In general the (empirical), total *EWD* ΔE of Green interactions is much higher. This is given by

Total $\Delta E_I = \int m(5\omega+2\delta)dm = (5\omega+2\delta)x^2/2$ ⟶ (5)

Total $\Delta E_D = \int m5\omega dm = (5\omega)x^2/2$ ⟶ (6)

The limits of the integral stretch from *0* to x, ω and δ are constants for any given message. The following table lists the *SPI* augmentation in relation to the *Greened* HL7-TCP/IP interactions.

TABLE 3. Performance Augmentation in *Greened* HL7-TCP/IP

PI	PI Name	Trend/Movement	Augmentation
1	**Usability** This refers to the ease of use or operation of the *Green* TCP/ IP-HL7V3 *Message* paradigm. It is a *simplified, more efficient, enhanced implementation.*	EWD for Green TCP/IP-HL7 (Immediate ACK process) $(5\omega + 2\delta)x^2/2$ units EWD for Green TCP/IP-HL7 (Deferred ACK process) = (5ω) $x^2/2$ units	Positive Usability is Enhanced $x \to \infty$, EWD of the *Green* interactions increase exponentially, by a power of 2.
2	**Applicability**	Proof in 1. demonstrates the greater applicability of the *Green* option over its regular counterpart in every situation.	Positive Applicability is Enhanced
3	**Stability**	Precision, controlled *Green* solution with enhancements like paired message flow, and the strict application of the *timeout* principle, augment message flow stability.	Positive Stability is Enhanced
4	**Efficiency**	Proposed *Green* TCP/IP-HL7 interactions are *exponentially* more efficient than the regular TCP/IP-HL7 interactions in terms of (EWD). (see 1)	Positive Efficiency is Enhanced
5	**Consistency**	The proposed *Green* solution is streamlined, with an optimized design for message flow and control. (see analysis (*E*))	Positive Consistency is Enhanced
6	**Resilience/ Robustness** Relates to factors which cause error or breakdown.	(1)*Error in data transmission and data read* - rectified by resend/reread. (2)*Inordinate delays by line-hog situations,* Handled by strict message control flow and *minimal* message cloud.	Positive Resilience/ Robustness is Enhanced
7	**Reliability** This refers mainly to two factors : i. Reliability in operation ii. Reliability of output.	i. is ensured by satisfaction of point 6. above ii. is ensured by satisfaction of points 3., 5., 8.	Positive Reliability is Enhanced

8	**Accuracy** The following *performance -related* empirical equation defines accuracy. *Stringent Control in Message Flow + Stability + Consistency + Resilience/Robustness + Reliability* = **System Accuracy**	The proposed Green TCP/IP-HL7 solution guarantees vast improvements and enhancements (as proved empirically) in all attributes on the left-hand-side (LHS)	Positive Accuracy is Enhanced
9	Scalability Relates to system scaling as x⟶∞	As shown in point 1., as the system(enterprise lattice) gets larger (Number of messages $x \longrightarrow \infty$) , the EWD of *Green* interactions increase exponentially, by a power of 2 affording *super-scalability*.	Positive Scalability is Enhanced
10	Versatality	The preceding nine positive attributes of the *Green* TCP/IP-HL7 solution enhances its versatility. The *Green* solution is a better choice and performer in every situation.	Positive Versatality is Enhanced

IV) CONCLUSION

This study examined the realization of *International Interoperability* and "*in-the-wire*" performance enhancement as *kindred* concerns. The proposed,*unified Greening* solution has direct relevance to both, thus signalling the achievement of every goal set at the outset. Li et al enunciated *hexa-level Semiotic Interoperability* in [12], articulating *Physical, Empiric, Syntactic, Semantic, Pragmatic*, and *Social* interoperability. Indeed, this unified *Greening* solution seamlessly overarches this semiotic framework; the *physical-empiric interoperability* integrations of the lowest two levels facilitated by the new greened *HL7-TCP/IP* interactions, the *syntactic-semantic interoperability* integrations facilitated by new, abridged green messaging structures, and the *pragmatic-social interoperability* obligations by the HL7-oriented system use and operation within the enterprise, and the enterprise's operation in the healthcare-related social realm. Thus, summing up, an approach that is *unified* and *universal* was key; hence the apt term *Unified Universal Green Messaging* and its principle objective *International Interoperability*.

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31/44