Admission-Discharge-Transfer Gateway Interface: A Health Level 7 Application

Mehmet S. Unluturk, and Coskun Atay

***Abstract*—**This paper presents a software application called Admission-Discharge-Transfer (ADT) Gateway Interface. This interface uses the Health Level 7 (HL7) standard to bridge the hospital computer systems for maintaining hospital bed occupancy. ADT Gateway Interface is a Microsoft VB.NET application that utilizes the Microsoft Windows TCP/IP socket to communicate with the Hospital Information System (HIS) ADT System. Received messages are processed using a custom Microsoft Windows DLL called HL7Messaging DLL and information presented inside these messages are put into a Microsoft SQL Server 2005 database. Hospital computer systems reach to this SQL Server 2005 database to examine the bed occupancy in the hospital. Furthermore, states and errors of this ADT Gateway Interface are recorded. This helps design engineers in measuring performance and observing failures and recoveries. This may require detail log information from this application. In this study, a robust logging viewer design methodology is used to improve reliability and consistency of the overall integrated system.

***Keywords*—**Health Level 7 **(**HL7), Microsoft SQL Server 2005, TCP/IP socket, Windows DLL.

I. INTRODUCTION

THIS paper employs an emerging standard of communications between hospital computer systems for maintaining the hospital bed occupancy. The standard is called Health Level 7 (HL7) [1]. The HL7 standard was established by an organization of hospital computer system vendors. The organization published a document that fully describes the requirements of the standard.

The HL7 standard has changed since its inception. The organization has been careful to maintain backward compatibility in succeeding versions of the standard. The implementation of this paper supports versions 2.2 and 2.3 of the standard.

The full implementation of the HL7 standard is intended to support all data exchange in the healthcare environment. ADT Gateway's interface requires a subset of the full implementation. This document describes that subset identifying specific format requirements. The following topics are presented in the next sections:

- Hardware Architecture
- HL7 Message Delivery Methods
- HL7 Message Structure
- HL7 Sample Messages

A. Hardware Architecture

ADT Gateway interface accepts delivery of HL7 messages using a Local Area Network (LAN). The LAN protocol used is Ethernet with the Transport Control Protocol/Internet Protocol (TCP/IP) layers running above Ethernet. The Gateway and its database serve as a repository for HL7 information to be drawn from when the Nurse Call Master Stations require bed status. The following diagram shows the relationship between the major components of the ADT Gateway interface.

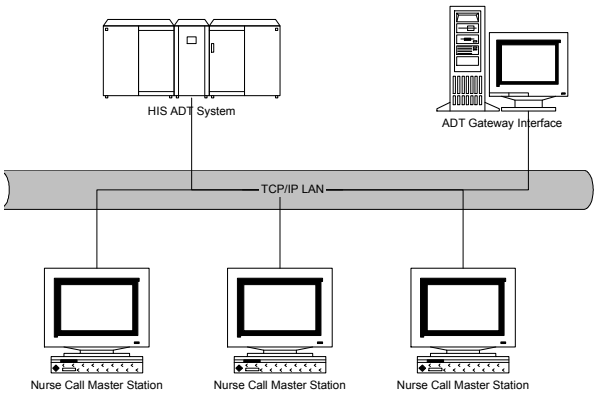

Figure 1. ADT Gateway Interface with its major components.

B. HL7 Message Delivery Methods

The Hospital Information (HIS) ADT System provides a Microsoft Windows TCP/IP socket. The socket port of the listener program is site configurable. The ADT Gateway establishes a socket connection with the HIS ADT System computer, and then receives the HL7 messages.

C. HL7 Message Structure

An HL7 message is divided into a set of segments. Each segment is divided into fields. Each field is divided into components. Each component is divided into sub-components. Sub-components are atomic.

Segments are identified by a three-letter character sequence at the start of the segment. The following table shows the

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HL7 segment three letter character sequences interpreted by the ADT Gateway Interface.

Segment Character Sequence	Purpose
MSH	Message Header
EVN	Event Type
PID	Patient ID
PV1	Patient Visit 1
PV2	Patient Visit 2
NK1	Next of Kin 1
NPU	Bed Status
MRG	Merge Patient Info.

Table 1. HL7 segment three letter character sequences

All other ADT segments are ignored. Message segments must be separated by the ASCII carriage return that is <CR> character (13). The Message Header segment uniquely identifies which operation should be performed. The header segment identifies the operation using the Message Type field. This field has two components: a Message Type and a Trigger Event.

Trigger Event String	Description
A01	Admit a patient
A02	Transfer a patient
A03	Discharge a patient
A04	Register a patient
A05	Pre-admit a patient
A06	Transfer an outpatient to inpatient
A07	Transfer an inpatient to outpatient
A08	Update patient information
A09	Patient departing
A10	Patient arriving
A11	Cancel admit
A12	Cancel Transfer
A13	Cancel discharge
A17	Swap Patients
A20	Nursing/Census application updates
A21	Leave of absence – out
A22	Leave of absence – in
A29	Delete person information
A30	Merge Person Information
A33	Cancel patient departing
A34	Merge Patient Information – patient ID only
A35	Merge Patient Information – account number only
A36	Merge Patient Information – patient ID and account number
P01	Add and update patient account

Table 2. The Trigger Event values

Any HL7 trigger event message sent that is not listed above is rejected. The ADT Gateway Interface accepts all HL7 message segments, but examines a subset of the segments to obtain the information supporting the nurse call master stations. The following table shows the minimum required and optional message segments provided for HL7 trigger events:

Trigger Event	Required segments	Optional Segments
A01 - Admit a patient	MSH, EVN, PID, PV1	PV2, NK1
A02 - Transfer a patient	MSH, EVN, PID, PV1	PV2, NK1
A03 - Discharge a patient	MSH, EVN, PID, PV1	PV2, NK1
A04 - Register a patient	MSH, EVN	
A05 - Preadmit a patient	MSH, EVN	
A06 - Transfer an outpatient to inpatient	MSH, EVN, PID, PV1	PV2, NK1
A07 - Transfer an inpatient to outpatient	MSH, EVN, PID, PV1	PV2, NK1
A08 - Update patient information	MSH, EVN, PID, PV1	PV2, NK1
A09 - Patient is departing	MSH, EVN, PID, PV1	PV2, NK1
A10 - Patient is arriving	MSH, EVN, PID, PV1	PV2, NK1
A11 - Cancel admit	MSH, EVN, PID, PV1	PV2, NK1
A12 – Cancel transfer	MSH, EVN, PID, PV1	PV2, NK1
A13 - Cancel discharge	MSH, EVN, PID, PV1	PV2, NK1
A17 – Swap Patients	MSH, EVN, PID, PV1	PV2, NK1
A20 - Nursing/Census application updates	MSH, EVN, NPU	
A21 - Leave of absence- out	MSH, EVN, PID, PV1	PV2, NK1
A22 - Leave of absence- in	MSH, EVN, PID, PV1	PV2, NK1
A29 - Transfer an outpatient to inpatient	MSH, EVN, PID, PV1	PV2, NK1
A30 - Merge Person Information	MSH, EVN, MRG	
A33 - Transfer an outpatient to inpatient	MSH, EVN, PID, PV1	PV2, NK1
A34 - Merge Patient Information Patient ID	MSH, EVN, MRG	

A35 - Merge Patient Information Account	MSH, EVN, MRG	
A36 - Merge Patient Information Patient ID and Account	MSH, EVN, MRG	
P01 – Add and update patient account	MSH, EVN, PID	

Table 3. Minimum required and optional message segments provided for HL7 trigger events.

The ADT Gateway does not preserve *Register* (A04), *Preadmit* (A05), *Delete patient information* (A29) and *Add and update patient account* (P01) patient and case data. These messages are ignored. Segments within these messages are validated and invalid fields are indicated in a rejection message.

The *Update patient information* (A08) message updates the ADT Gateway record when the associated patient and case is found in the Gateway's database. The message is ignored when the patient record is not found. The Gateway requires the full set of available patient information for the *Admit a patient* (A01) trigger event. The *Transfer an inpatient to outpatient* (A07) and *Patient Departing* (A09) messages are handled like a *Discharge* (A03) with one minor difference. The PV1 segment's Prior Patient Location field is used as the discharge location rather than the Assigned Patient Location field used in the A03 message. The Gateway requires the full set of available patient information in both sets of PID, PV1 and optional PV2 segments for the *Swap patients* (A17) trigger event.

D. Field Data Character Restrictions

The ADT Gateway stores most printable seven-bit ASCII characters defined from Hexadecimal 20 through 7E inclusive. It does not record characters identified in the following restrictions.

- The ADT Gateway does not support the use of the escape character specified in the encoding characters.
- Any double quote (“) characters are stripped from the field data before it is recorded in the Gateway's database.
- Field separators and segment separators are not recorded when included as field data.

E. Message Header (MSH) Requirements

All HL7 messages are required to begin with the MSH segment. The table below shows the name of each field of the MSH segment. Also shown are the field's maximum width and when the field is required or ignored.

Field Name	HL7 Item	Max Size-chars	Required / Ignored
Field Separator	1	1	Required
Encoding Characters	2	4	Required
Sending Application	3	15	Ignored
Sending Facility	4	20	Ignored
Receiving Application	5	30	Required
Receiving Facility	6	30	Required
Date/Time Of Msg.	7	26	Ignored
Security	8	40	Ignored
Message Type	9	7	Required
Message Control ID	10	20	Ignored
Processing ID	11	1	Required
Version ID	12	8	Required
Sequence number	13	15	Ignored
Continuation pointer	14	180	Ignored
Accept ack. type	15	2	Ignored
Application acknowledge type	16	2	Ignored
Country code	17	2	Ignored
Character Set	692	6	Ignored
Principle Language Of Message	693	60	Ignored

Table 4. Maximum and minimum fields for MSH segment

The Field Separator field defines the character by which all fields within segments will be separated. The “|” character is typically used as the separator character.

The Encoding Characters field must contain four characters in the following order: the Component Separator character; Repetition Separator character; Escape character; and Sub-component Separator character. The recommended values are ^~\&.

The Message Type field has two components called Message Type and Trigger Event. The Message Type component must be “ADT”. The Trigger Event component must be one of the following character strings: A01, A02, A03, A04, A05, A06, A07, A08, A09, A10, A11, A12, A13, A17, A20, A21, A22, A29, A30, A33, A34, A35, A36, P01. The Processing ID field can contain any character string, but it cannot be blank. The Version ID field must be “2.2” or “2.3”.

F. Event Type (EVN) Requirements

The table below shows the name of each field of the EVN segment. Also shown are the field's maximum width and when the field is required or ignored.

Field Name	HL7 Item	Max Size (chars)	Required / Ignored
Event Type Code	99	3	Ignored
Date/Time of Event	100	26	Required
Date/Time Plan. Event	101	26	Ignored
Event Reason Code	102	3	Ignored

Operator ID	103	5	Ignored
Event Occurred	1278	26	Ignored

Table 5. Maximum and minimum fields for EVN segment

The Date/Time of Event field is a time stamp field that must be in the YYYYMMDDHHMM format where YYYY is the year, MM is the month, DD is the day, HH is the hour, and MM is the minute.

G. Patient Identification (PID) Requirements

The table below shows the name of each field of the PID segment. Also shown are the field's maximum width and when the field is required, stored or ignored.

Field Name	HL7 Item	Max Size (chars)	Required / Ignored
Set ID	104	4	Ignored
Patient ID (External)	105	16	Ignored
Patient ID (Internal)	106	20	Required
Alternate Patient ID	107	12	Ignored
Patient Name	108	48	Stored
Mother's Maiden Name	109	30	Ignored
Date of Birth	110	26	Stored
Sex	111	1	Stored
Patient Alias	112	48	Ignored
Race	113	1	Stored
Patient Address	114	106	Stored
County code	115	4	Ignored
Phone Number - Home	116	40	Stored
Phone Number - Business	117	40	Ignored
Language - Patient	118	60	Stored
Marital Status	119	1	Ignored
Religion	120	3	Stored
Patient Account Number	121	20	Required
SSN Number - Patient	122	16	Ignored
Driver's License Num	123	25	Ignored
Mother's Identifier	124	20	Ignored
Ethnic Group	125	1	Ignored
Birth Place	126	25	Ignored
Multiple Birth Indicator	127	2	Ignored
Birth Order	128	2	Ignored
Citizenship	129	3	Ignored
Veterans Military Status	130	60	Ignored
Nationality	739	80	Ignored
Patient Death Date /Time	740	26	Ignored
Patient Death Indicator	741	1	Ignored

Table 6. Maximum and minimum fields for PID segment

The Patient ID field uniquely identifies the patient. An example of this ID might be the medical record number or a billing number. The Date of Birth field must be in the Time Stamp format that is YYYYMMDD.

H. Patient Visit 1 (PV1) Requirements

The table below shows the name of each field of the PV1 segment. Also shown are the field's maximum width and when the field is required or ignored.

Field Name	HL7 Item	Max Size (chars)	Required / Ignored
Set ID - Patient Visit	131	4	Ignored
Patient Class	132	1	Ignored
Assigned Patient Location	133	80	Required
Admission Type	134	2	Ignored
Preadmit Number	135	20	Ignored
Prior Patient Location	136	80	Required *
Attending Doctor	137	60	Stored
Referring Doctor	138	60	Ignored
Consulting Doctor	139	60	Stored
Hospital Service	140	3	Stored
Temporary Location	141	12	Ignored
Preadmit Test Indicator	142	2	Ignored
Readmission indicator	143	2	Ignored
Admit Source	144	3	Ignored
Ambulatory Status	145	2	Ignored
VIP Indicator	146	2	Stored
Admitting Doctor	147	60	Stored
Patient Type	148	2	Stored
Visit Number	149	15	Ignored
Financial Class	150	50	Ignored
Charge Price Indicator	151	2	Ignored
Courtesy Code	152	2	Ignored
Credit Rating	153	2	Ignored
Contract Code	154	2	Ignored
Contract Effective Date	155	8	Ignored
Contract Amount	156	12	Ignored
Contract Period	157	3	Ignored
Interest Code	158	2	Ignored
Transfer to Bad Debt Code	159	1	Ignored
Transfer to Bad Debt Date	160	8	Ignored
Bad Debt Agency Code	161	10	Ignored
Bad Debt Transfer Amount	162	12	Ignored
Bad Debt Recovery Amount	163	12	Ignored
Delete Account Indicator	164	1	Ignored
Delete Account Date	165	8	Ignored
Discharge Disposition	166	3	Ignored
Discharge to Location	167	25	Ignored
Diet Type	168	2	Ignored
Servicing Facility	169	2	Ignored
Bed Status	170	1	Ignored
Account Status	171	2	Ignored
Pending Location	172	12	Ignored
Prior Temporary Location	173	12	Ignored
Admit Date/Time	174	26	Stored
Discharge Date/Time	175	26	Stored
Current Patient Balance	176	12	Ignored
Total Charges	177	12	Ignored
Total Adjustments	178	12	Ignored

Total Payments	179	12	Ignored
Alternate Visit ID	180	20	Ignored
Visit Indicator	1226	1	Ignored
Other Healthcare Provider	1224	60	Ignored

Table 7. Maximum and minimum fields for PV1 segment

The Assigned Patient Location field contains the location of the physical bed assigned to the patient. The field has five components: nursing unit; room number; bed ID; facility and bed status. The Component Separator character must separate each component.

The ADT Gateway parsing of this field supports a variety of component usage. The room number can be provided alone while the other components are empty. The nursing unit component can be provided alone while the other components are empty. Both the room number and nursing unit cannot be empty in the same field value. The parsing implements the HL7 standard for component separators such that the separators between empty components trailing valued components need not be included in the field.

The Prior Patient Location field contains the location of the physical bed assigned to the patient before the patient was transferred to the Assigned Patient Location. This field is required when the Trigger Event is a *Transfer Patient*, *Transfer inpatient to outpatient*, *Patient Departing* or *Cancel Transfer* message (A02, A07, A09 and A12) otherwise it is ignored. The field has four components: facility; nursing unit; room number and bed ID. The Component Separator character must separate each component. The field is parsed in the same manner described for the Assigned Patient Location field.

The Admit Date/Time field is a Time Stamp field that must be in the YYYYMMDDHHMM format where YYYY is the year, MM is the month, DD is the day, HH is the hour, and MM is the minute.

The Discharge Date/Time field is a Time Stamp field that must be in the YYYYMMDDHHMM format where YYYY is the year, MM is the month, DD is the day, HH is the hour, and MM is the minute. It is required when the Trigger Event is discharge (A03) otherwise it is ignored.

I. Patient Visit 2 (PV2) Requirements

The table below shows the name of each field of the PV2 segment. Also shown are the field's maximum width and when the field is required or ignored.

Field Name	HL7 Item	Max Size (chars)	Required / Ignored
Prior Pending Location	181	12	Ignored
Accommodation Code	182	60	Stored
Admit Reason	183	60	Stored
Transfer Reason	184	60	Stored
Patient Valuables	185	25	Ignored
Patient Valuables Location	186	25	Ignored
Visit User Code	187	2	Ignored
Expected Admit Date	188	8	Ignored
Expected Discharge Date	189	8	Ignored
Est. Length of Inpatient Stay	711	3	Ignored
Actual Length of Inpatient Stay	712	3	Ignored
Visit Description	713	50	Ignored
Referral Source Code	714	90	Ignored
Previous Service Code	715	8	Ignored
Emp. Illness Related Indicator	716	1	Ignored
Purge Status Code	717	1	Ignored
Purge Status Date	718	8	Ignored
Special Program Code	719	2	Ignored
Retention Indicator	720	1	Ignored
Exp. Number of Insurance Plans	721	1	Ignored
Visit Publicity Code	722	1	Ignored
Visit Protection Indicator	723	1	Ignored
Clinic Organization Name	724	90	Ignored
Patient Status Code	725	2	Ignored
Visit Priority Code	726	1	Ignored
Previous Treatment Date	727	8	Ignored
Expected Discharge Disposition	728	2	Ignored
Signature on File Date	729	8	Ignored
First Similar Illness Date	730	8	Ignored
Patient Charge Adjustment Code	731	3	Ignored
Recurring Service Code	732	2	Ignored
Billing Media Code	733	1	Ignored
Expected Surgery Date & Time	734	26	Ignored
Military Partnership Code	735	2	Ignored
Military Non-Availability Code	736	2	Ignored
Newborn Baby Indicator	737	1	Ignored
Baby Detained Indicator	738	1	Ignored

Table 8. Maximum and minimum fields for PV2 segment

The Accommodation Code field indicates the specific patient accommodations for this visit. The Admit Reason field supports a short description of the reason for admission. The Transfer Reason field provides a short description of the reason for a transfer. It is required when the Trigger Event is transfer (A02) otherwise it is ignored.

J. Next of Kin (NK1) Requirements

Next of Kin segments can be delivered in multiples to facilitate one or more patient contacts. The HL7 standard for this segment includes a Set ID field to differentiate each contact. The MIS Gateway stores the first NK1 segment data provided in the message, subsequent segments are ignored.

The table below shows the name of each field of the NK1 segment. Also shown are the field's maximum width and when the field is required or ignored.

Field Name	HL7 Item	Max Size (chars)	Required / Ignored
Set ID - Next of Kin	190	4	Ignored
Name	191	48	Stored
Relationship	192	60	Ignored
Address	193	106	Ignored
Phone Number	194	40	Stored

Business Phone Number	195	40	Ignored
Contact Role	196	60	Ignored
Start Date	197	8	Ignored
End Date	198	8	Ignored
Next of Kin Job Title	199	60	Ignored
Next of Kin Job Code/Class	200	20	Ignored
Next of Kin Emp. Number	201	20	Ignored
Organization Name	202	60	Ignored
Marital Status	119	2	Ignored
Sex	111	1	Ignored
Date/Time of Birth	110	26	Ignored
Living Dependency	755	2	Ignored
Ambulatory Status	145	2	Ignored
Citizenship	129	4	Ignored
Primary Language	118	60	Ignored
Living Arrangement	742	2	Ignored
Publicity Indicator	743	1	Ignored
Protection Indicator	744	1	Ignored
Student Indicator	745	2	Ignored
Religion	120	3	Ignored
Mother's Maiden Name	746	48	Ignored
Nationality	739	80	Ignored
Ethnic Group	125	3	Ignored
Contact Reason	747	80	Ignored
Contact Person's Name	748	48	Ignored
Contact Person's Tel. Number	749	40	Ignored
Contact Person's Address	750	106	Ignored
Next of Kin/Assoc. Party's Id.	751	32	Ignored
Job Status	752	2	Ignored
Race	113	1	Ignored
Handicap	753	2	Ignored
Contact Person SSN	754	16	Ignored

Table 9. Maximum and minimum fields for NK1 segment

The Relationship field defines the personal relationship that the next of kin has to the patient. Examples might include brother, sister, mother, father, friend, spouse, emergency contact, employer. The Phone Number field defines the telephone number of the associated party.

K. Bed Status Update (NPU) Requirements

The table below shows the name of each field of the NPU segment. Also shown are the field's maximum width and when the field is required or ignored.

Field Name	HL7 Item	Max Size (chars)	Required / Ignored
Bed Location	209	12	Required
Bed Status	170	1	Stored

Table 10. Maximum and minimum fields for NPU segment

The Bed Location field contains the location of the physical bed whose status is to be set according the Bed Status field. The field has five components: nursing unit; room number; bed ID; facility and bed status. The Component Separator character must separate each component.

L. Merge Patient Information (MRG) Requirements

The table below shows the name of each field of the MRG segment. Also shown are the field's maximum width and when the field is required or ignored.

Field Name	HL7 Item	Max Size (Chars)	Required / Ignored
Prior Patient ID - Internal	211	20	Required for A30, A34, A36 trigger events
Prior Alternate Patient ID	212	16	Ignored
Prior Patient Account #	213	20	Required for A35 and A36 trigger events
Prior Patient ID - External	214	16	Ignored
Prior Visit Number	1279	20	Ignored
Prior Alternate Visit ID	1280	20	Ignored
Prior Patient Name	1281	48	Ignored

Table 11. Maximum and minimum fields for MRG segment

The Prior Patient ID - internal field is required when the trigger event identifies that the HL7 transaction contains a new patient ID. The Prior Patient Account Number field is required when the trigger event identifies that the HL7 transaction contains a new account number.

M. HL7 Message Samples

A01 Admit a patient

MSH|^~\&|REGADT|MCM|PCAPP|GATEWAY|198808181320|SECURITY|ADT^A01|MSG00002|P|2.2|<cr>
EVN|18|198808181318||<cr>
PID|||PATID5678^9^M11||JONES^WILLIAM^A^JR||19310615|M||C|303 EDWARDS
...DRIVE^GREENSBORO^NC^27410|GL|(919)294-1212|(919)288-
...0101||M||PATID12345001^2^M10|987654321|143257^NC|<cr>
NK1|1|JONES^NANCY^K|WIFE||(214)355-5678<cr>
PV1|1|I|1WES^100^1^A||||004777^LEBAUER^SIDNEY^J.|||SUR||||||||||||||||||||||||||||||199606011300|<cr>
PV2||P^PRIVATE^HIS|ADMIT REASON|TRANSFER REASON|PATIENT VALUABLES<cr>
AL1|1|DA|Allergy code|SEVERITY|REACTION|199612310101<cr>

A02 Transfer a patient

MSH|^~\&|REGADT|MCM|PCAPP|GATEWAY|198808181320|SECURITY|ADT^A02|MSG00002|P|2.2|<cr>
EVN|18|198808181318||<cr>
PID|||PATID5678^9^M11||JONES^WILLIAM^A^JR||19310615|M||C|303 EDWARDS
...DRIVE^GREENSBORO^NC^27410|GL|(919)294-1212|(919)288-
...0101||M||PATID12345001^2^M10|987654321|143257^NC|<cr>
NK1|1|JONES^NANCY^K|WIFE||(214)355-5678<cr>
PV1|1|I|1EAS^100^1^A|||1WES^100^1^A|004777^LEBAUER^SIDNEY^J.|||SUR||||||||||||||||||||||||||||||199606011300|<cr>
PV2||P^PRIVATE^HIS|ADMIT REASON|TRANSFER REASON|PATIENT VALUABLES<cr>
AL1|1|DA|Allergy code|SEVERITY|REACTION|199612310101<cr>

A03 Discharge a patient

MSH|^~\&|REGADT|MCM|PCAPP|GATEWAY|198808181320|SECURITY|ADT^A03|MSG00002|P|2.2|<cr>
EVN|18|198808181318||<cr>
PID|||PATID8^9^M11||GABBERT^PETER^B^||19520615|M||C|1910 PIONEER PARKWAY^ST.
...CHARLES^IL^60506|GL|(708)294-1212|(708)288-
0101||M||PATID5001^2^M10|987654321|143257^NC|<cr>
NK1|1|ZONTRALIO^LAURA^P|WIFE||(214)355-5678<cr>
PV1|1|I|1WES^100^1^A||||102104^GRANT^JAMES^M.|||PED||||||||||||||||||||||||||||||199606011300|199607041300<cr>
PV2||P^PRIVATE^HIS|ADMIT REASON|TRANSFER REASON|PATIENT VALUABLES<cr>
AL1|1|DA|Allergy code|SEVERITY|REACTION|19961231010<cr>

II. HL7 MESSAGING DLL

Component based development is used during the implementation of the DLL. This component is tested once and can be used in several applications [2-6]. When HL7 message strings are received through socket from HIS ADT System (see Figure 1), *HL7Message* object is populated. HL7Message class diagram is shown in Figure 2.

HL7EventType, HL7MessageHeader and HL7PatientID classes are also shown in Figure 3. Then newly created HL7Message object writes itself into the SQL Server 2005 database. Other class diagrams such as the ones for HL7PatientVisit1, HL7PatientVisit2, and HL7NPUSegment and so on are not shown in this paper for brevity.

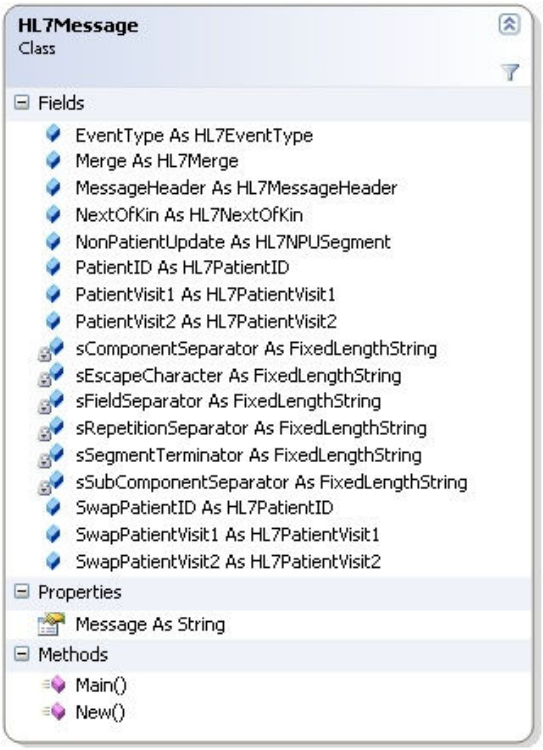

Figure 2. HL7 Message class diagram

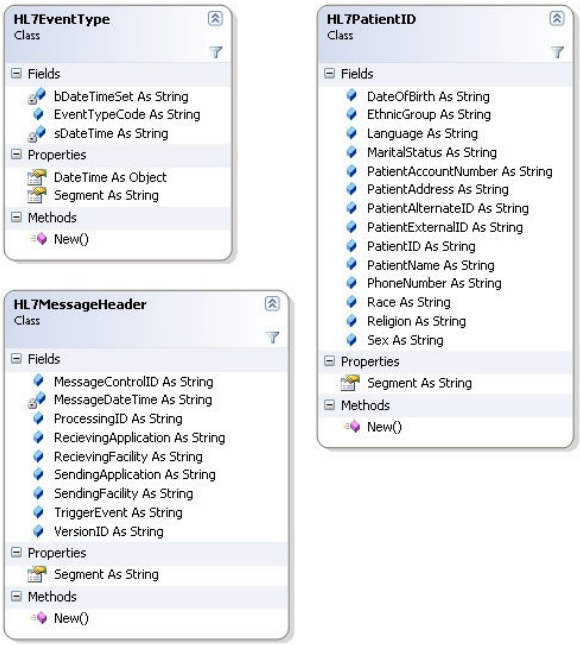

Figure 3. Class diagrams for HL7EventType, HL7MessageHeader and HL7PatientID.

ADT Gateway Interface requires a database access to insert HL7Message object into database. UML class diagram that is given in Figure 4 is implemented for the interface between ADT Gateway application and database. Each database connection requires a connection object, and a command object. They are defined inside the interface called

IDatabaseAccess. Main class *DatabaseAccess* holds a queue of connection objects. Connection objects are wrapped inside *DBCon* class which implements the *IDatabaseAccess* interface.

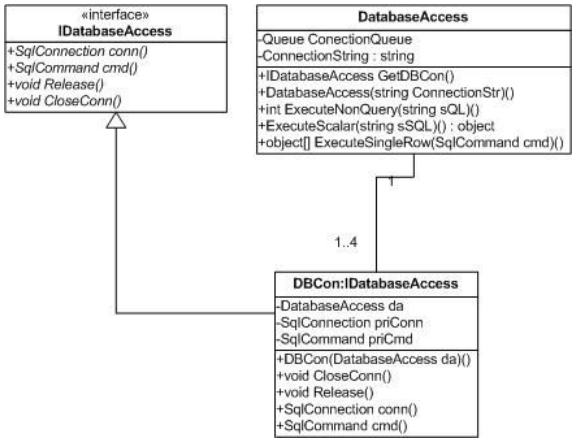

Figure 4. UML class diagram for database access

III. LOGGING

The best way to assess ADT Gateway Interface's robustness and performance while running is to employ a logging component where states and errors of interface are traced. A log entry is simply a formatted message that contains important information that can be used during analysis [7-11]. A well-formed log entry includes the following information:

Logging Level: Logging is broken into five levels, with the most critical events logged at level-4 and less critical events logged at levels 3, 2, 1 and 0. Level-0 events are heartbeat messages that are sent to target at regular intervals. Level-1 events consist of non-critical communication messages such as warning messages. Level-2 events represent recoverable errors which mean system recovers from errors without user involvement. Level-3 events hold critical events which require user attention. Finally, level-4 events contain link failures and recoveries.

Statistic Name: Each log message at each logging level is recorded with a statistic name. These names are used in generation of statistics for each application. For example, FAIL and RECOVER are the statistic names for level 4 events. They always appear in pairs. No two FAILs follow each other. These statistics depict when the application fails and recovers successfully.

Message: Message section of the log entry holds the actual message. This actual message is either the error or the state of the application. These verbose messages help developers to debug applications in debug mode or to investigate performance in release mode.

As the log entries are recorded by ADT Interface, it calculates the statistics. When the Interface runs for the first time, it takes the current time as the statistic start up time and the link up time. At the end of each minute, as long as the socket is connected to the HIS ADT System, Interface adds 1 minute to the link up time. Link up time value is saved into the database. Next time, when Interface is started, it reads the previous value from the database and continues adding 1 minute. Hence, *Tot_Run_Time* is calculated as the time difference between current time and statistic start time. Total run time statistic value helps the designer to determine how long the Interface is running.

$$Tot\_Run\_Time = CurrentTime - Statistic\_Start\_Time \quad (3.1)$$

Up_Time is the indicator that shows how long the Interface's link is up and running in percentages.

$$Up\_Time = \frac{Linkup\_Time}{Tot\_Run\_Time} \quad (3.2)$$

Mean Time To Recover depicts the average time of recovering from failures in number of days, hours, minutes and seconds. It is calculated as

$$Mean\_Time\_To\_\text{Recover} = \frac{CurrentTime - Linkup\_Time}{\#\ of\ \text{Recoveries}} \quad (3.3)$$

Mean Time To Failure indicates the average time of how often the failure is occurred within the ADT Gateway Interface. It is given as

$$Mean\_Time\_To\_Failure = \frac{Linkup\_Time - Statistic\_Start\_Time}{Number\ of\ Fails} \quad (3.4)$$

Mean Time To Error shows the average time of errors happened inside the software application and is given as

$$Mean\_Time\_To\_Error = \frac{Linkup\_Time - Statistic\_Start\_Time}{Number\ of\ Errors} \quad (3.5)$$

Other metrics are also used such as Message_Success_Ratio which is given as

$$Msg\_Success\_Ratio = \frac{Number\ of\ Messages}{Number\ of\ Messages + Number\ of\ Errors} \quad (3.6)$$

Figure 5 displays the UML class diagram for the logging component that is called *DiagnosticLogControl*. *ConnectionString* is used to connect to the database. Definition for *DatabaseAccess* is given in Figure 4. ADT Gateway Interface executes *AddLogMsg* to add messages into the component. As the log messages are added, component runs the *UpdateStats()* method to populate the current statistics. Component also executes the *CalcRunningTotals()*

method to calculate the overall statistics and writes them into the database.

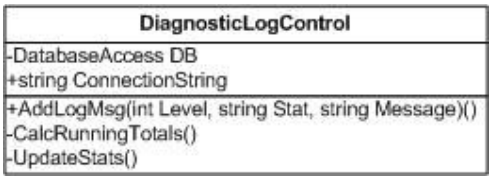

Figure 5. UML class diagram for logging component

IV. RESULTS

HL7 is a standard for hospital information systems. The ADT Gateway Interface uses a subset of it to maintain bed occupancy in a hospital. It receives ADT (admit, discharge, transfer) messages through windows socket from HIS ADT System. Data is processed by HL7Messaging DLL and is written into a database which is read by other nurse call master stations. Furthermore, we used a tool that is designed to trace the performance of ADT Gateway Interface. As the errors and events are happening, *logging component* calculates the current statistics and then, calculates the overall statistics and put them in the database (Equations 3.1 through 3.6). Designers can use this tool to see the performance of any .NET applications in production mode. They can also use such a tool in debug mode to catch logical or run-time errors within .NET applications.

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