Workflow-based Lifecycle Modeling: A Paradigm for the Analysis and Architecture Of Enterprise-wide e-Health Applications

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Abstract

This paper gives an overview of a set of methods for effectively architecting complex workflow-driven electronic healthcare, or e-Health, applications for distribution across diverse health care enterprises. The highlighted application, known as CareCompass™, is a commercially available clinical automation system implemented for the Home Health and Post-acute health care markets. This paper discusses aspects of the Home Health domain, which form the basis of understanding the need for a lifecycle-based workflow model. Then, it discusses aspects of the model, using the Home Health domain as an example, pertaining to the paradigm for creating a life-cycle model comprised of artifacts, each with its own constituent state sequencing. The basic premise of this workshop paper is that these modeling techniques, and the abstract pattern that is derived from it, form an effective means to create a flexible, customizable and extensible architecture for implementing a workflow-based clinical information system across a diverse health care enterprise.

1. Introduction

Health care executives are grappling with a climate of great change in the industry. This is coming from a number of sources. First, there is increased activism from consumers and employers who want a greater say in health care service delivery and reimbursement options. There is also increased pressure to make operations more efficient in response to the need to hold down spiraling costs, better manage utilization of health care resources, and more effectively compete in health care markets. Finally, there is increased regulatory scrutiny across the spectrum of service providers, service payers and life science companies.

Through the adoption of advanced information technologies (IT), including the Internet, many health care organizations are transforming the ways in which they do business in this chaotic business climate. Electronic health care, or *e-Health*, is making it possible for health care executives to leverage the power of greater automation, better workflow, and more effective deployment of IT across their organizations to better manage their cost structure, while also improving their delivery of service.

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In this paper, we discuss a set of methods for quickly analyzing and architecting complex clinical e-Health applications for delivery across diverse health care enterprises. These methods are based on the following notions:

- Complex clinical management processes consist of a sequence of process steps, involving people playing many different roles, that invariably involve the movement of information (in the form of rigidly-defined clinical and financial documents) through the organization.
- There is a patient (or customer or agent) on which the organization's processes act. This action is represented in a computing system as a series of actions taken to change the status of the patient as reflected by changes or additions to the organization's documents.
- This sequencing of activities around the patient and the corroborating documents forms a workflow, and the status of information in the document artifacts constitutes the current state of affairs pertaining to the patient under care. The joining together of these process activities, and the sequencing of these states forms a lifecycle.
- Each document artifact, and each patient or customer under care, has its own specifically defined lifecycle, each with its own set of allowable state sequences. These state sequences a business analyst can capture a priori, and can enter into a workflow system in order to explicitly represent the lifecycle processes to be supported by the system.
- Such formulations are very flexible, extensible and customizable—all important attributes desired of e-Health applications to allow systems to grow and evolve over time, and allowing their respective organizations to reap returns many times over their original IT system investment.

This paper presents the conceptual model for the state-based lifecycle analysis pattern, followed by a discussion of the basic artifacts and processes associated with a Home Health enterprise. We then discuss the interesting aspects of the model and their relationship to the selected application architecture, and how that architecture is realized in a diverse health care enterprise.

2. System Conceptual Model

2.1. Characterizing the Architecture

Before we can discuss the artifacts themselves, we need to discuss the environment (and typical structure) of a Post-acute care business. This business deals with the delivery of care to patients who are homebound, as a result of age-related deterioration in health, or as a result of procedures of care requiring at-home convalescence. It should be noted that the basic sequence of activities—in fact, the very organization of the business, is built around adherence to a clinical methodology of care. In this case, Home Health uses the basic nursing process, adapted for the needs of care delivery in the patient's home.

It should be noted that the authors have studied several such clinical domains, and has found them to conform to the same basic workflow organization. This generic organization of processes around a set of document-based artifacts constitutes the architectural "pattern". Such enterprise-level business patterns are becoming recognized as being directly applicable to the identification and selection of appropriate system architectures.

In considering the functionality of the example, we partition the CareCompass™[1] application into a constituent set of functional components, laid out into an architecture that maximizes flexibility, customizability and extensibility. This partitioning represents the system model that will be used to articulate and develop the lifecycle descriptions in the later section of this paper.

[1] CareCompass™ is a trademark of HealthMagic, Inc.

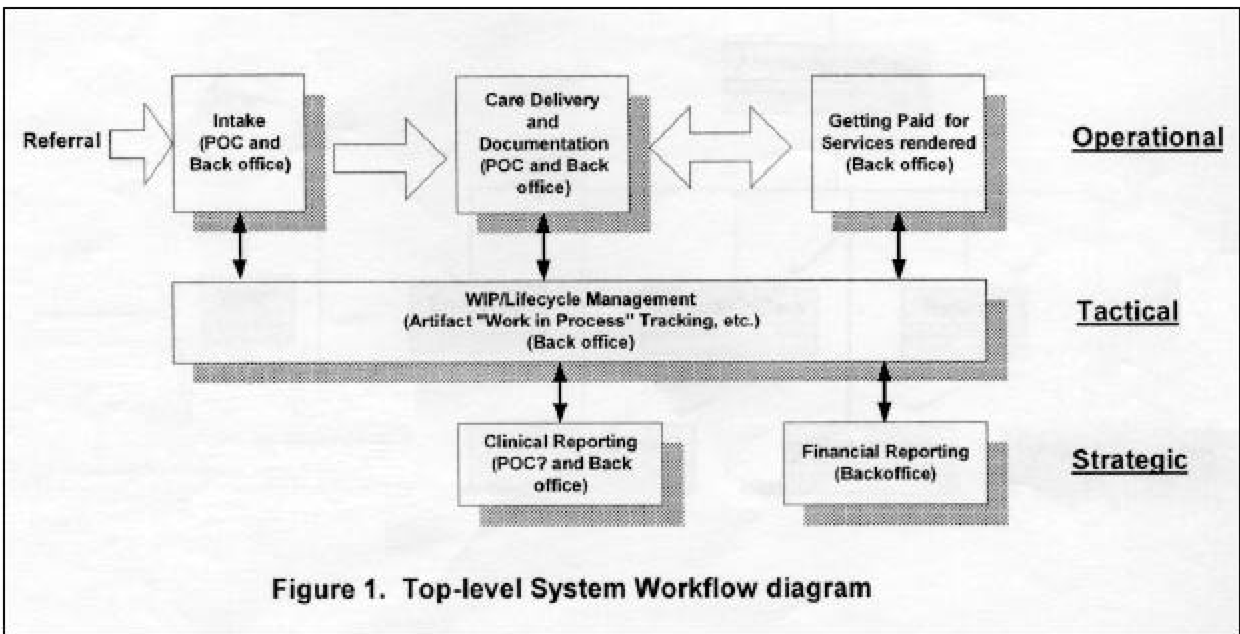

Figure 1. Top-level System Workflow diagram

As depicted in Figure 1, there is a primary flow of work indicated, starting with the "Referral" of a patient to the Home Health (or Post-acute Care) Agency. This figure takes the patient referral through the following process sequence. First, the referral passes through the Intake business process. Next, the resulting program admission representing the patient passes into the Care Delivery process, where actual care is delivered to the patient and is documented according to agency and regulatory guidelines for practice.

Finally, each clinical encounter with the patient culminates with passing the occurrence through to those processes associated with the Agency being paid for services rendered by the appropriate Payer(s). The workflows associated with these business processes are indicated in the figure as those that are "operational" in nature--they constitute the day-to-day execution of the business on a continuous basis.

Also depicted in the figure is a box located at the "tactical" level of business functioning, labeled "WIP/Lifecycle Management". This component encapsulates all system functionality of CareCompass™ facilitating the back-office workflows associated with managing the flow of documentation and information through the healthcare enterprise. The use of a "WIP" model indicates we are following the practice used in manufacturing concerns of tracking the status of "work in process".

Since a Home Health Agency or enterprise gets paid for services based on some notion of "work", the components of this workflow need to be explicitly tracked and managed. The Lifecycle management component provides a set of interfaces and services, allowing the end user--as well as other modules in the system itself--to act upon the abstract artifacts representing the flow of work through the enterprise. Note that there may be many different end users, each representing an agency staff member playing different roles in the various back-office processes. The functionality and tasks encapsulated in this component are "tactical" in nature--they are associated with insuring effective and optimal operation of the business in satisfying the Enterprise's specific business performance objectives.

Many aspects of running a Home Health Agency require conformance to regulatory guidelines that are temporal in nature (i.e., are time-based). Time-in-process becomes a critical concern--in the same way that time in process for product inventory would be critical for cost management for a factory. A business objective for Home Health Agencies is thus to minimize work in process, i.e., the amount of time an "artifact" stays active in the process by not completing its passage through its requisite sequence of lifecycle states. Furthermore, as a

result of HCFA[2] guidelines, there are hard constraints on the amount of time a specific unit of work (such as an unsigned Assessment form) can be in process. This component will implement the set of functionality that allows monitoring and management of the artifacts, to insure that specific tactical business objectives are met.

Finally, as depicted in Figure 1, there are several components indicated to be "strategic" in nature--in that they are concerned with facilitating the Enterprise's management with tools for meeting strategic business objectives. These objectives are more aligned with patient outcomes and financial performance of the agencies. The primary functionality in these components is provision of reporting capabilities. The Clinical and Financial Reporting components are shown as separate boxes primarily because of the different objectives that each part of the business pursues. However, they could be implemented as a single subsystem.

2.2. Characterizing the Home Health Problem Domain

The complex weave of clinical procedure in care delivery with changing business and regulatory realities has made Home Health a difficult problem domain in which to devise an effective computing solution to meet the demands of the market. This complexity comes from several basic characteristics of the Home Care enterprise and its general business model.

- The delivery of quality health care to a homebound population encompasses a highly *distributed*--yet *synchronous*, *coordinated* and *tightly coupled*--range of activities. It involves collecting timely information and dispensing care services across an oftentimes-large geographical area. It also involves coordinating care for a patient among multiple clinicians as well as the physician(s) and other service providers.

- The deployment of agency clinical staff resources, management of materials and supplies, and coordination of patient care among multiple disciplines requires a sophistication of planning and schedule logistics management. As is quite the case, these activities must be performed in a *noisy*, *dynamic* and *non-monotonic* environment. In other words, most information obtained from and about the patient of care can be suspect--and thus subject to revision, affecting the outcome of the delivery of care and payment for services. In addition, the plan and schedule of care for a patient is dynamic and is often subject to high volatility. A clinician may be scheduled to visit a patient to deliver care, but the patient may not be home for a variety of reasons--thus forcing the clinician to adapt the care plan and reschedule the visit. Finally, a patient's condition may change significantly, causing the clinical team to re-plan the treatment.

- The nature of many aspects of the clinical and financial workflows involves completing key tasks within pre-specified regulatory time windows. Missing these time windows--for example, in the submission of POC/485 forms--has a negative effect on the business. Furthermore, timing of events in the delivery and documentation of care, as well as in being paid for services rendered, can be interdependent across tasks and events. For instance, the time points for OASIS events may be partially ordered but are sequentially time dependent.

- The execution of a Home Health enterprise's workflow involves all of these *interacting sub-problems* crossing the clinical space (in a multitude of clinical disciplines) as well as the financial space (covering the range of financial and administrative business functions). The results of clinical care, and its concomitant documentation, affect the financial transactions, and vise versa. With PPS, the nature of the regulatory constraints become more restrictive on the business, in terms of the timing and payment amounts, for a large sector of the managed patient population.

In many domains, acceptable solutions to these problems involve doing one of the following: making simplifying assumptions to reduce the complexity of the product solution to be implemented; or, identifying abstractions allowing the management of inherent complexity such that a flexible, extensible and conceptually simpler suite

[2] HCFA is the Health Care Finance Administration, an agency of the US Government responsible for Medicare funding, in addition to regulations and guidelines associated with billing for services, outcomes and certain practice guidelines.

of applications can be devised. The CareCompass™ development program has sought to employ both strategies to obtain a leading edge position in the marketplace. What follows is a discussion of an appropriate set of abstractions for addressing the above problem traits.

Before doing so, however, we should make one additional statement about this application by way of example. We are constructing a system for a set of workflows and business processes that do not yet exist. In other words, one of the requirements for this system all along has been to not automate the existing paper-based procedures in use today. Rather, the intent has been to come up with new processes, supported by a well-founded clinical methodology, and build the system to support these new processes. This brings us to an important point associated with the analysis methods and architecture pattern presented in this paper: a large part of the process of creating automated solutions involves doing the requisite business process definition such that there are appropriate manual procedures in place for which the automated enterprise system can support. Furthermore, the creation and implementation of these processes must be carried out either before, or in parallel, with the systems development process.

As such, the focus of the CareCompass™ Clinical Automation system is on leveraging and magnifying the productivity and decision-making capacity of the various knowledge workers in the Home Health enterprise. Each of these plays a role in the completion of the various workflows required in operating the business, delivering the care, and getting the payment for services. Therefore--in defining a conceptual model for the system--our task is to create an abstraction allowing the various users to effectively interact with the system to complete their workflow tasks. In addition, our task is to find methods to assist these users, where possible, in managing the inherent complexity of their work environment. The system should address these concerns by providing the following services in the back-office:

- Facilitating coordination among workflow participants,
- Managing dependencies among workflow tasks,
- Tracking the critical time windows imposed by business and regulatory factors, and,
- Reporting timely information for steering the business

In doing so, the system will increase productivity and improve the financial health and competitiveness of the Home health enterprise.

3. Modeling Domain Workflow with Lifecycle Abstractions

As stated, the Home Health enterprise consists of a number of coordinated, interdependent workflows, mainly paper-based today, but for which we will largely automate. In the short-term, we will not be able to eliminate the complete "paper trail" that exists and is still required by regulatory surveyors. However, we desire to support the effective management of these elements, or "artifacts", of the workflows in the back-office, and thus enable the healthcare knowledge workers to better manage the complexity of their work environment.

In this workshop paper, we present a conceptual model defined to allow this objective to be met. We use the basic abstraction of the "artifact" and its "lifecycle". In this, we recognize another important principle in the construction of enterprise applications: interacting artifacts--and users interacting with artifacts through a browser user interface--can have the effect of chaining together a sequence of events and actions affecting the flow of real work through the enterprise. This flow can be affected in terms of what is stored in the system about the status of each corresponding real-world thing represented by the artifacts (such as documents, billings and the like). The flow can also be affected by the actions taken by a user to make changes to the underlying state of an artifact through the user interface.

Here, we discuss the characteristics of the state-based lifecycle abstraction. We present how its use allows us to solve our problems (as stated in the previous section), and what descriptive elements we'll use to document this state-based behavior and the interactions between artifacts, and between artifacts and end users. In the next section, we take each of the identified artifacts, in turn, and develop the narrative of its underlying lifecycle

model, paying special attention to the business rules and domain constraints that must be enforced for correctness.

3.1. Overview of artifacts and the state-based lifecycle

In the Home Health enterprise, we are dealing with a number of things whose basic status changes over time. As a natural course of business, the statuses are of interest, but also the time sensitivity of the status changes. For example, a standard OASIS Assessment for a patient undergoes a series of ordered transformations over time as it is acted upon by the clinicians and the Home Health Agency. This series of ordered steps is referred to as a "lifecycle", and the individual steps themselves are known as "states". They are both significant to healthcare knowledge workers, as they are used to track the movement of work through the enterprise, and are thus a very natural means of thinking about the elements, or "artifacts", of work.

More formally, a state is a stable, discrete state of existence for some artifact (such as an Assessment document) where certain policies, practices and activities apply to the artifact while it is in that state. An example would be the unsigned state of an Assessment form, where certain rules apply to its handling that would differ from those that would apply once it has been signed by the authoring clinician.

It has been observed that a core set of artifacts in the Home Health enterprise have discrete states that they transition through. Furthermore, we observe that the ordering and sequencing of these states for a given artifact is *deterministic*. In other words, the set of possible state sequences for an artifact can be specified beforehand, and can therefore be encoded and understood by the system. Finally, this state sequencing directly correlates to the workflow that is carried out on the artifact. This becomes significant, since we can build this sequencing into the system's underlying data structures, thus driving the workflows through the enterprise.

There is a comprehensive set of artifacts having this behavioral characteristic of a state-based lifecycle in the Home Health enterprise. As shown in Figure 2, there are two broad categories of artifacts--those corresponding, or representing, real world documents (*DocumentArtifacts*), and those representing other types of sequencing relations in the workflow (*RelationArtifacts*). The first category includes artifacts representing documents such as Assessments, Care Plans, and Visit Notes. The second category includes more abstract, "relational" notions in the Home Health domain, such as Encounter (or Visit), Episode of Care, and Program Admission.

The artifacts of both categories share the following basic characteristics:

- They are created by the system as a result of a specific creation event, either initiated by an end user through the U/I or by actions taken by another artifact. For example, when the back-office component detects that a new Assessment form has been completed and signed for patient 'John Smith', a new Assessment artifact would need to be created by the system, being placed into the appropriate state.

- While cycling through their various states, actions are carried out by the artifacts representing workflow in the enterprise. An action is an activity that must be performed. The action exists either in the system or in the external in the environment. If the specified action exists outside of the system, it implies that the action is some task to be performed by the end user. In order to indicate to the system that the user has performed the action, the user through the U/I must inform the artifact. For example, a valid action for a completed Assessment form is that it is to be signed by a clinician. If the clinician subsequently signs the document, the clinician or an administrator in the back-office would enter this information, such as via a checkbox for the given Assessment form, indicating that it has been signed. Specific actions are associated with specific states of an artifact's lifecycle. The user will be restricted from performing these actions in the system unless the artifact is in the appropriate state for such action to be taken.

- They cycle through their various state sequences based on the occurrence of events to which they are sensitive while in a given state. Something can happen causing the artifact to change its state. The happening is referred to as an *event*. The lifecycle model for a specific type of artifact is defined with the

events to which it is sensitive for each of its given states. Furthermore, the lifecycle indicates what the artifact is to do if the event is received. Generally, the event is received to have the artifact to transition to a new state.

- They most likely reach a terminal state, where further action on the artifact by the system is severely limited. In this terminal state, the system would generally limit access to the underlying system object for viewing, reporting or archiving purposes only.

- Sometimes artifacts are forced into a state where they are replaced by a newly created artifact in the system. This is versioning or "replay" of the artifact, where the original version is kept for historical purposes (usually required for regulatory reasons), although the new version is the one that continues being operated on by the system.

- Artifacts are time-sensitive, in that they carry all information about timestamps as to when they entered a specific state in their lifecycle. It may be that only some entry dates of an artifact's states are significant in the lifecycle, in which case only those dates would be stored in the underlying database. The use of timestamps allows time point calculations to be performed. These will be used in generating report *flow sheets* (such as those paper ones used in many agencies today) and in calculating timeout ranges.

The DocumentArtifact category of artifacts share many characteristics not held by RelationArtifact types, namely the following:

- All document instances in the system are created from a source template for that document category. Each source document template may have versions. Each template version may have its own lifecycle with a set of valid state transitions (such as “Active” and “Discontinued”). This state information of templates might be used in the content distribution between the Back-office and an offline “point of care” device, such as a laptop PC, used in the field--if such templates were to be cached locally.

- All documents are of a given *category* and may also have a specific *type*. For example, Assessment document is the *category*, but SOC (start of care) Assessment would be the *type* of Assessment document.

- All documents have a *creator* (Author) as well as an *owner*. In addition, documents have *signatories*. Usually the author, a Clinician, is a *signor*, whereas some document categories require additional signatures, such as from Agency Supervisor and Attending Physician.

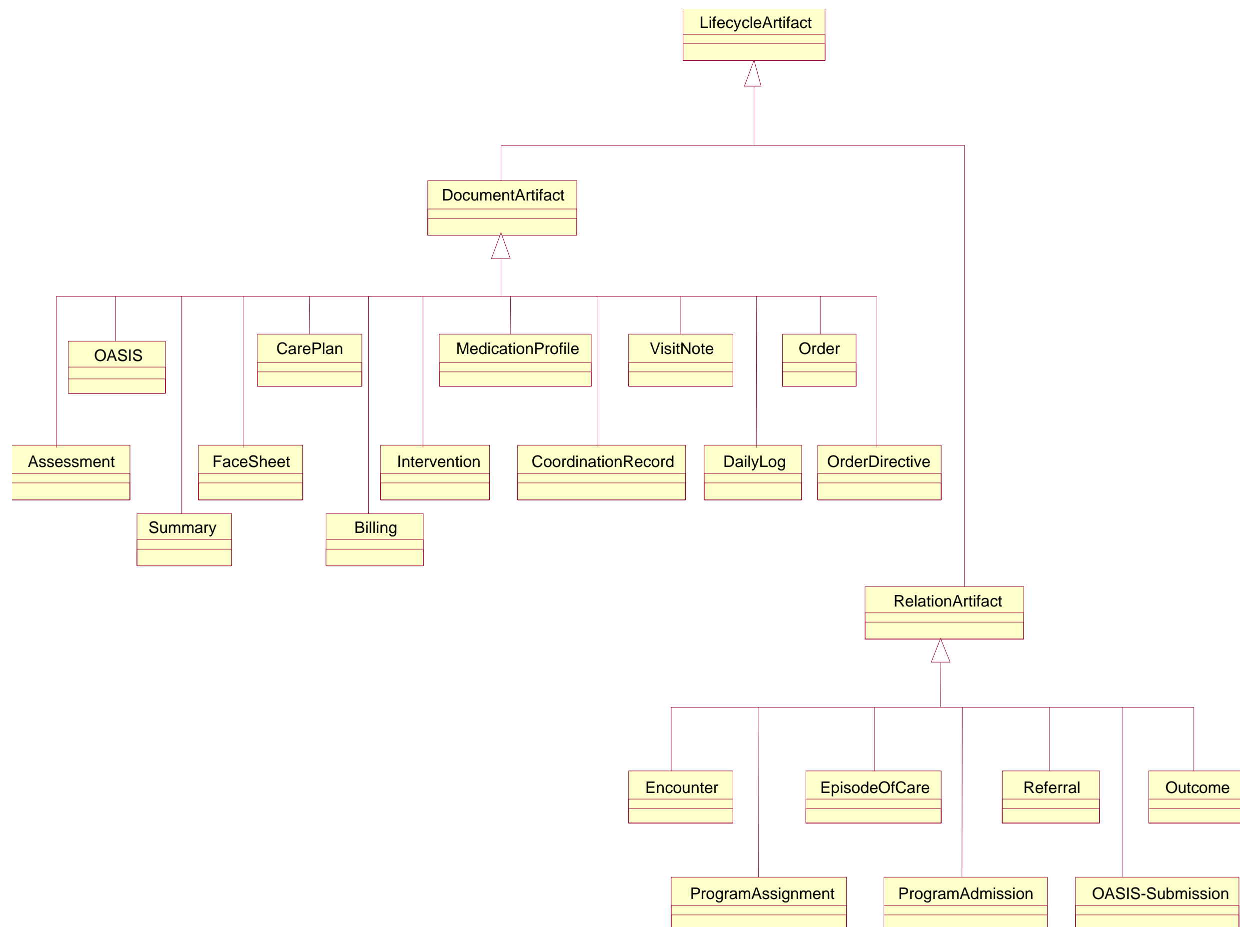

Figure 2. Taxonomy of Artifact Types.

- Some document categories are defined such that they consist of document components, or *sub-documents*, which themselves may be treated as document *categories*. In other words, a document may be atomic, or it may be a compound artifact that can be decomposed into other compound or atomic document artifacts. Each component document category has its own state-based lifecycle, which may be implicitly embedded in the lifecycle of the compound document artifact.

3.2. How the abstraction works in practice

The use of lifecycle artifacts in the management of document workflow can be described as follows. There is a means whereby actual renderings of electronic clinical documents will be distributed to the POC device or used in the office. Such documents exist as templates, implemented in some technology and managed by other software components in CareCompass™. Our interest in this specification is not what technologies are used or how the documents are rendered or stored but, rather, that the system has a means to manage their lifecycles.

Each document category has a collection of allowable state sequences constituting its lifecycle. The defined sequencing for a particular document is significant, in that it follows the workflow of the document--whether in electronic or paper form--as it moves through the enterprise. Each document created as a result of a clinician delivering and documenting patient care results in an instance of one of the document artifacts being created in this component. As the clinician and other healthcare staff act upon the real document, the artifact instance's state information is updated to reflect the latest status of the real document. Sometimes the state transition can

take place due to a triggering event, while other transitions may be initiated directly by an end user (either a clinician or data entry coordinator).

As the state of the document artifact is updated to reflect the current status of the real document, the system is able to perform meaningful tasks on behalf of the users. For instance, the implemented artifact may perform specific actions upon entering the new state, such as sending messages to other artifacts.

In addition, the artifact could provide information indicating which User Interface functions are valid for a set of screens given the selection of the current document. This would allow the "graying out" (i.e., invalidating certain U/I buttons in the browser interface from accepting input) of functions, so that invalid functions are not available to users when the artifact is in a given state. The state-specific behaviors for each document category will not be fully specified in this paper; however, the basic mechanisms for doing so are outlined.

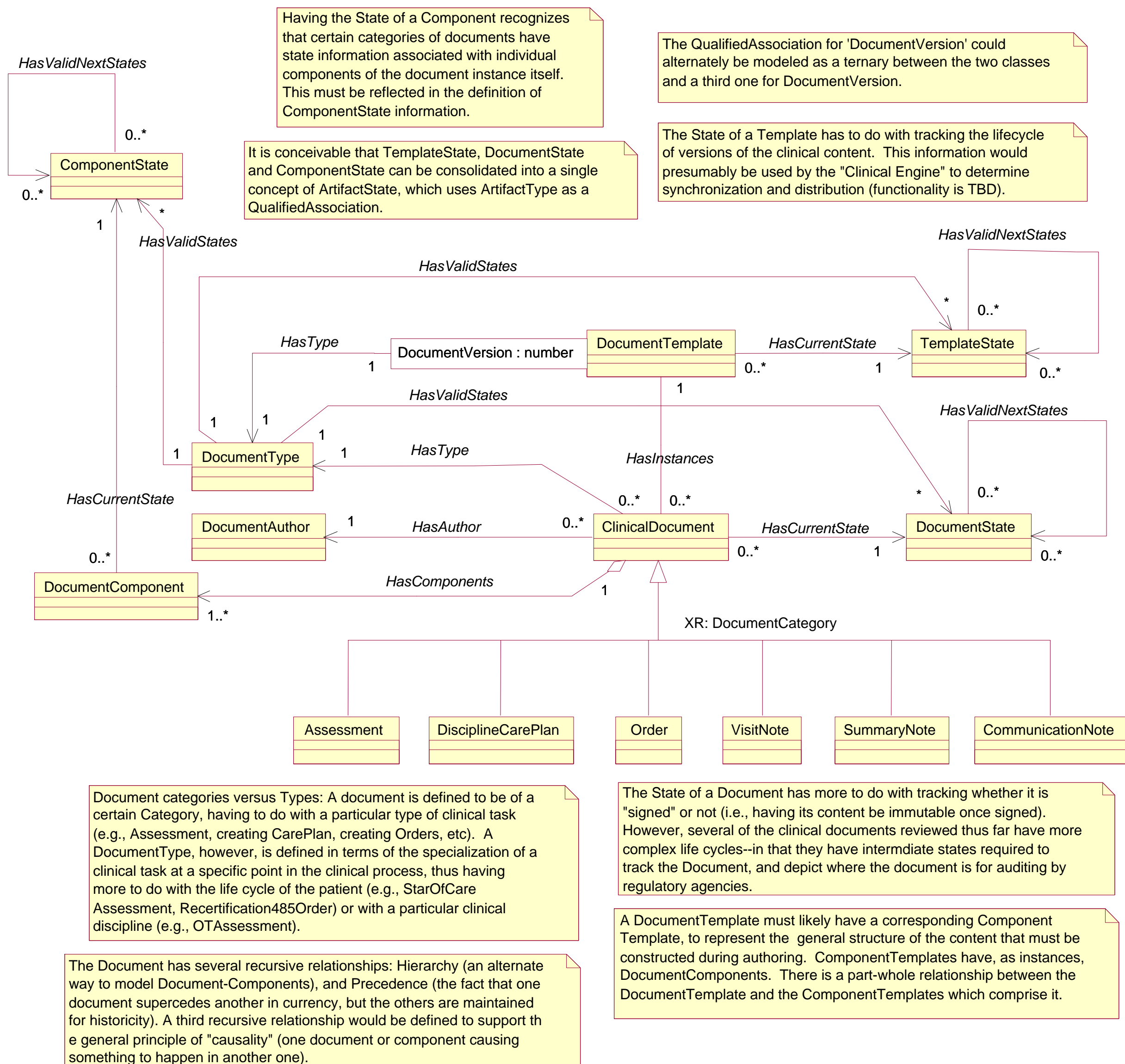

Figure 3. Conceptual Model of Document Artifact.

4. State-based Lifecycle Example

In this section, we present an example of our approach using the Home Health domain example presented earlier. We present a subset of important artifacts and their respective lifecycles, discussing the specific rules and constraints for each. We start in the order in which the artifacts are likely created as a result of a patient entering the sphere of care of the Home Health Agency and flowing into the core clinical care process. This order is shown in the business process model depicted in Figure 4. We open with an overview of the clinical process, to set the stage for describing the example enterprise artifacts, their state-based lifecycles, and how this state-based information is used to carry out meaningful work in the health care enterprise.

4.1. Overview of the Clinical Process

As we saw in Figure 1, there is a component of the system associated with the Intake process. During Intake, a referral for a patient is received by the agency. A set of activities ensues to collect information on the patient regarding the referral so that a decision can be made as whether to accept the referral or not. Factors such as insurance eligibility, ability to pay for services, geographical location, homebound status, among others, are considered when making this decision.

If a patient referral is accepted by the agency, the patient still requires an evaluation to decide whether s/he will be admitted for care. The decision to admit the patient is based on additional factors not considered during evaluation of whether to accept or reject the referral. This invariably requires a visit be made by a duly certified clinician to the patient's home to assess the patient's status and the patient's propensity to benefit from a regimen of care provided by the agency.

Upon assessing the patient, the attending clinician decides whether the patient will be admitted for care in one or more of the agencies programs of care. The clinician may decide that the patient could benefit from receiving care under multiple agency programs simultaneously. At this point, the patient is admitted for care, and care commences usually on this initial visit. By accepting the patient, the clinician sets in motion a number of factors that must be acted upon by different entities in the Home Health enterprise. Each of these factors is to be tracked by the Back-office component according to its specific state-based lifecycle. At this point the episode of care begins.

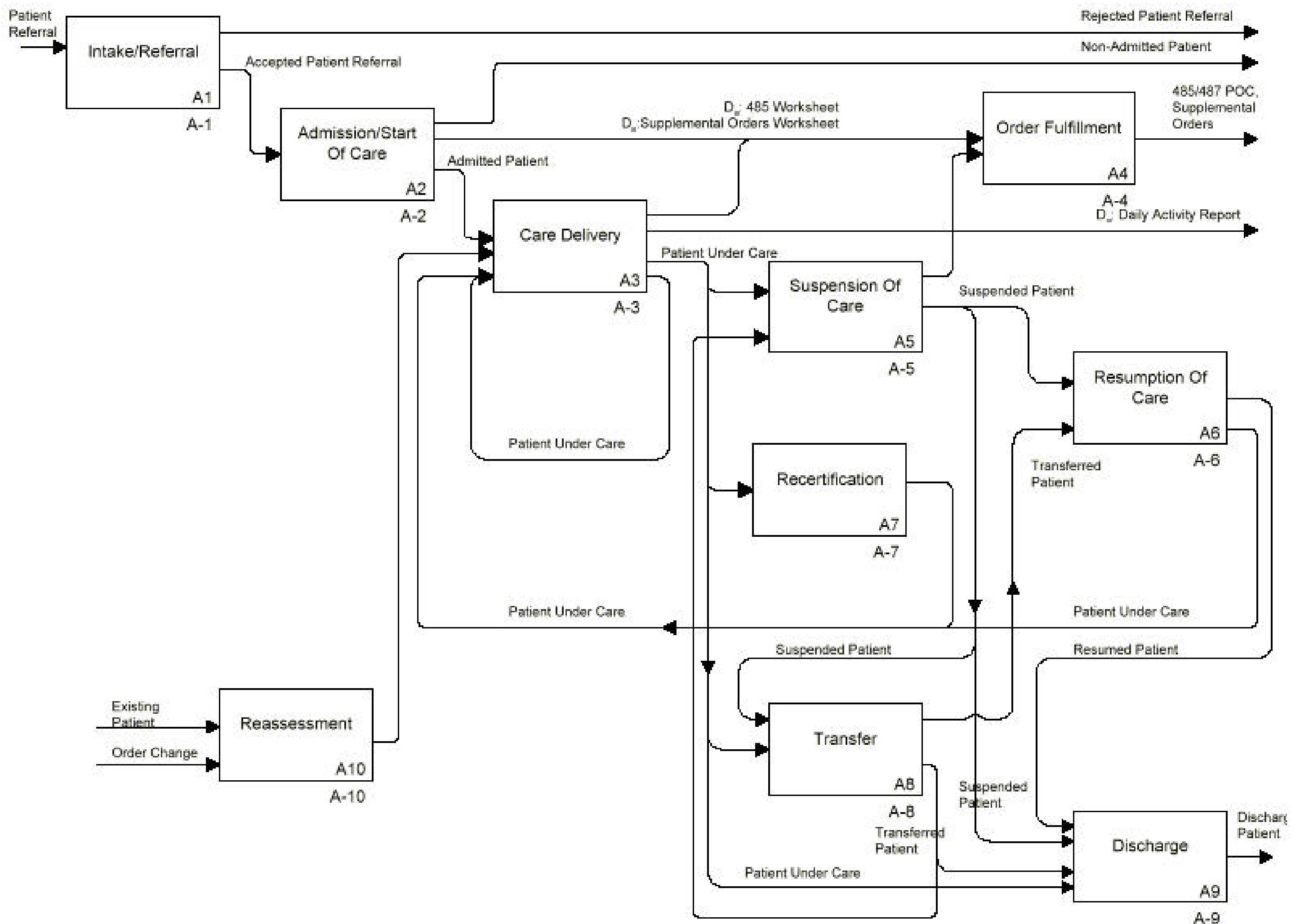

Figure 4. Clinical Process IDEF0 Model.

One of the conditions for delivering care is that the attending physician for the patient authorizes the care given to the patient. This authorization is given as a set of orders for a plan of care, and may initially be given "verbally" as part of the referral. Once the clinician has made an initial assessment of the patient, s/he drafts a set of orders, consisting of a number of directives, which must be signed by the physician. There are several Order document types allowing this to be done, depending on when during the episode of care the signing of orders is requested by the clinician. Outstanding orders for a patient have a time horizon over which they are valid. Once this period expires, the patient must have new orders for care drafted and the patient must be recertified for care in the programs to which s/he was admitted. Otherwise, the patient must be discharged from the agency's care.

While the patient is actively receiving care, the clinician makes scheduled visits the patient's home. As part of the clinical care delivery methodology (not presented in this specification), the clinician documents the care on a number of different documents. Various types of Assessment documents are used to capture the status of the patient and his/her environment, depending on when during the episode of care the visit is made and the assessment is performed. The clinician prepares a Care Plan for the patient, which is updated frequently during the episode of care. This care plan establishes the set of expected outcomes (or, Goals) for the patient and the set of Interventions to be performed, along with their frequency and duration, during delivery of care.

Once care is delivered according to the Care Plan, it is duly documented on a Visit Note. The Visit Note's contents will likely be generated from data garnered from the Assessment and the Care Plan. In addition, any

procedures not covered under an existing physician's order must have an Order (such as a 485 or Supplemental Order) form completed. Finally, the attending clinician documents the visit on a time sheet, the Daily Log, which is used downstream for Agency payroll and billing.

As mentioned, care is delivered for the course of the episode of care (for Medicare, this is 60 calendar days), at which time the patient may be recertified for another "cert. period" or discharged from the programs of care. Recertification consists of performing a comprehensive re-assessment the patient, developing a new Care Plan, and obtaining a new set of signed Orders for the proposed plan of care. The delivery of patient care could also be interrupted by one of the following events: transfer of the patient to an Inpatient facility, suspension of care because the patient is otherwise unavailable for care, or death of the patient. Each of these events affects the status of the program admission and its corresponding episode of care.

4.2. Artifacts of the Intake Process

Figure 5 depicts the conceptual domain model for the key concepts and relations associated with managing lifecycles for artifacts in the Intake workflow. The principal hierarchy of relations exists between a Patient and one or more Referrals of the patient to the Home Health enterprise. A patient can be referred on many occasions, each of which may not be disjoint in time (in other words, one or more referrals may overlap in time).

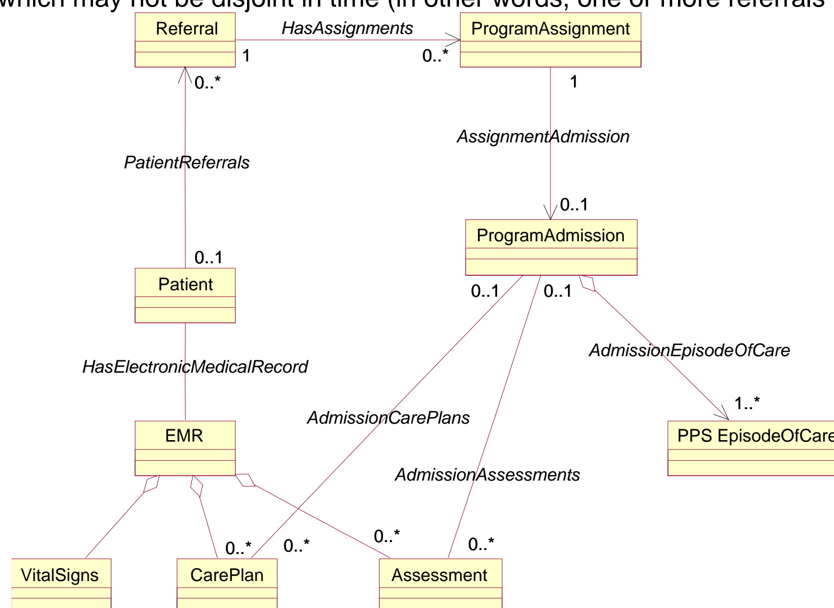

Figure 5. Conceptual Model for Intake Process Artifacts.

A given Referral, if accepted by the agency, results in one or more Program Assignments. As part of the same referral, a patient could be assigned for evaluation by clinicians in different programs of care. Each such program assignment may result in an Admission to that program, depending on the results of the clinical evaluation. Once admitted to one or more programs of care, a new Episode of Care is established for each admission.

4.3. The Referral artifact lifecycle

A Referral artifact would be created at the time a new referral is entered into the CareCompass system via one of its Intake screens. The specific U/I screen sequence is not relevant to the development of this specification. Suffice to say that, once the user creates a new referral (resulting in one or more records written in the database for the referral), a new Referral artifact should also be created. This Referral should be initialized to

the Incomplete state. The state transition diagram (STD) in Figure 6 shows the sequencing of states for a given Referral artifact.

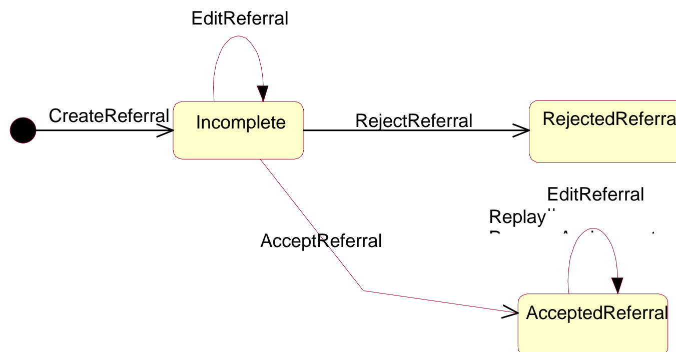

Figure 6. Referral Artifact Lifecycle diagram.

While the Referral artifact is in the Incomplete state, the referral information associated with the patient can be edited. The Intake process has a significant amount of patient information that must be collected as part of evaluating whether to accept the referral. Availability of the editing function might be exposed to the end user as an enabled button on a U/I screen or some sort. In addition, while in this state, the user can update the status of the patient referral to indicate that it is either accepted or rejected. Updating this status through some U/I mechanism results in the Referral artifact transitioning from the Incomplete state to either the RejectedReferral state or the AcceptedReferral state.

Once accepted, the referral enters the AcceptedReferral state. In this state, the referral can continue to be edited. This is because additional data must be collected for the patient as part of evaluating the patient's admissions status. Note that, in this state, the subsequently created ProgramAssignment may also be "replayed" through the U/I (as discussed in the next section). Alternately, if a referral is rejected, placing it in the RejectedReferral state, the referral cannot be operated on by the U/I other than for viewing in a list or report, by status, or viewing its associated historical data record.

4.4. The ProgramAssignment artifact lifecycle

Once a patient referral is accepted into one or more of the Home Health agency's programs of care, new instances of ProgramAssignment artifacts are created--one for each program assignment for the patient. The action of the Referral Artifact entering the AcceptedReferral state should cause the event signaling the creation of the ProgramAssignment artifacts.

Note that we don't dictate how the program assignment process is performed or how it is exposed through the CareCompass U/I. However, the user must perform two actions in order for a ProgramAssignment artifact to be properly initialized. First, the user must indicate that a particular patient referral has been accepted and, second, the user must indicate the specific agency program of care. It is a U/I design decision as to whether multiple assignments must be performed individually or can be done in combination (such as by selecting agency programs from a Multiple-select List Box in the U/I).

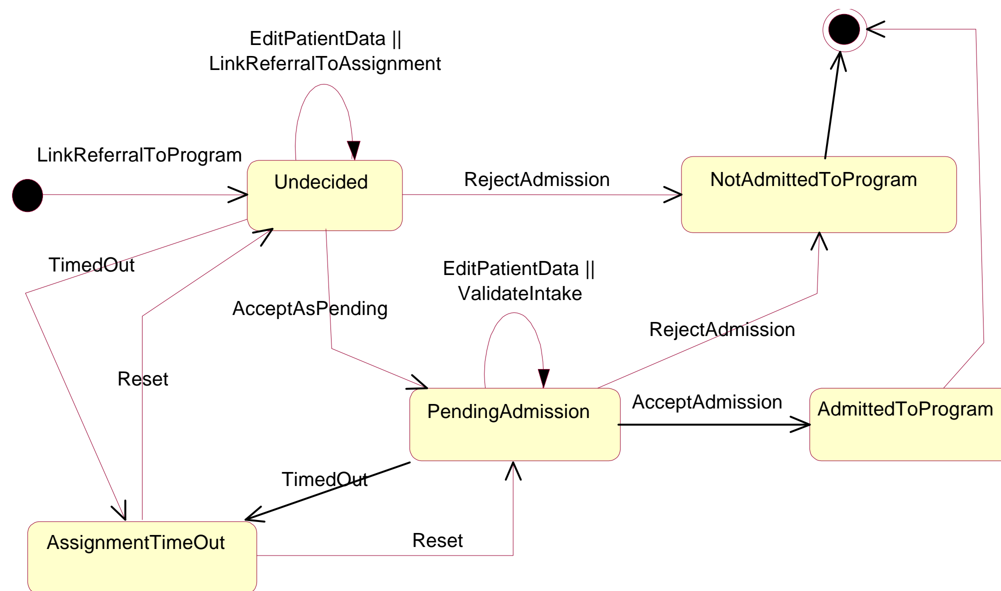

Figure 7. ProgramAssignment Artifact Lifecycle diagram.

The lifecycle diagram is depicted in Figure 7 for the ProgramAssignment artifact. The event labeled as Link Referral to Program initiates creation of the artifact instance, placing it into the Undecided state. This indicates that it is not yet known whether the patient is to be admitted into the assigned program of care. While in this state, data can continue to be entered into the patient's medical record. In addition, the Referral artifact is automatically linked to the ProgramAssignment artifact.

Finally, on entering the Undecided state, a "watchdog" timer should be initialized for the given ProgramAssignment. The timer is to be set up around the length of time that the assignment artifact can exist not being either admitted or rejected for admission into the program. This time frame is significant, in that an assignment can't be held in either the Undecided or PendingAdmission states indefinitely. In fact, agencies have specific time limits on this length of time.

By supporting the setting of timers, the system can help the agency keep track of the bookkeeping associated with these time frames, alerting an Administrator when the time is about to be exceeded for a set of assigned referrals. Presumably, the agency staff would have some procedure to insure that appropriate action is taken--for example, make sure an admissions visit is scheduled and assessment of the patient's condition is performed. To facilitate this, the system might send a reminder to an appropriate staff member, such as the Intake Supervisor, indicating that the referral assignment is tardy in closure. Note, once the timer has gone off, it needs to be reset and the artifact needs to transition back to the originating state.

During the valid window of time before the timer is exceeded for the given program assignment, the end user changes the status of the assignment to a "pending" status. This indicates that the agency has scheduled a clinician to make a visit to the patient's home to make an evaluation for admission. The user makes a status change through the U/I, causing the associated ProgramAssignment artifact for the patient's referral to transition to the PendingAdmission state. Alternately, a decision could be made to reject the patient's admission into the program outright, without making an evaluation visit. In this case, the user would interact with the system U/I in such a way as to cause a transition to the NotAdmittedToProgram state.

While in the PendingAdmission state, patient data can continue to be entered and modified in the patient's medical record. In addition, once the assignment has been "pended" and all patient data has been collected, the system could provide some Validation checks of the Intake data set. However, there is no firm requirement in the current roadmap for such a function. As long as the watchdog timer doesn't expire, the user can indicate through the U/I that the admission has been either accepted or rejected for the program referral. If the user indicates that the admission is jejected into the program of care, the corresponding artifact transitions to the

NotAdmittedToProgram state. Conversely, if the user indicates that the patient has been admitted to care, the artifact transitions to the AdmittedToProgram state. On entry to this state, a message should be sent to create an instance of a ProgramAdmission artifact for the newly admitted patient.

4.5. The ProgramAdmission artifact lifecycle

Figure 8 depicts the lifecycle model for the ProgramAdmission artifact. An instance is created on accepting the patient into the specified program of care. We have not stated how this information is communicated to the system, only that there must be a U/I element that allows this information to be entered. It could be indirectly conveyed by the creation of a SOC Assessment for the current episode of care, but this treats program admission as a side effect of assessment, which is not the case.

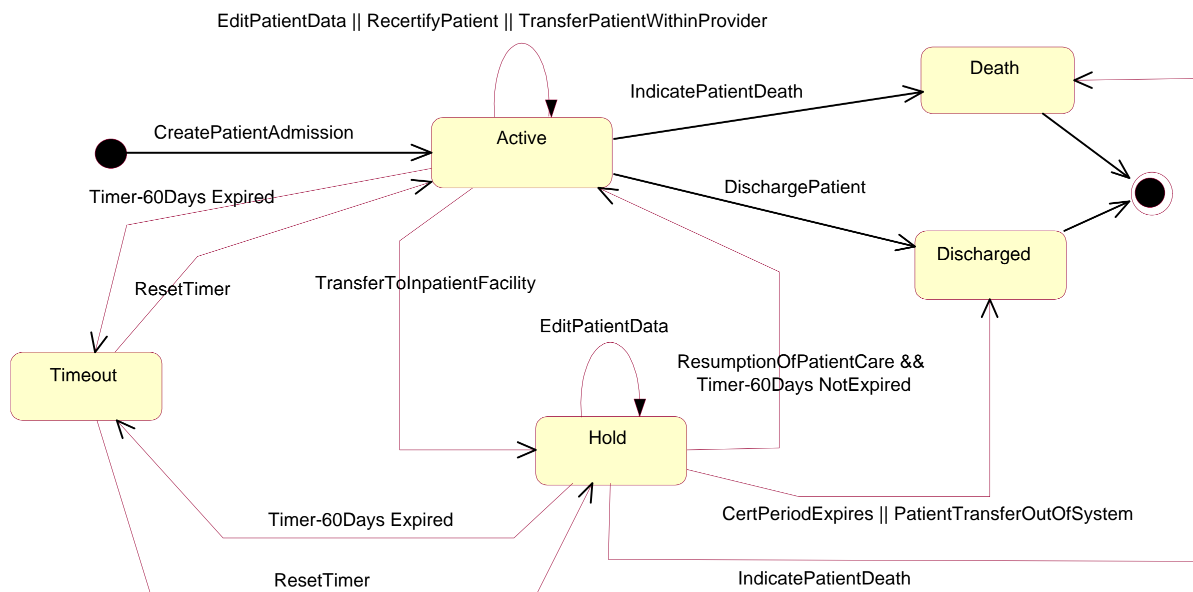

Figure 8. ProgramAdmission Artifact Lifecycle diagram.

On creation of a ProgramAdmission artifact, the instance is initialized to the Active state. There is a set of valid events that can be performed by the user, leaving the artifact in the Active state. First, as before, the patient's record can be edited (which, by this point in the clinical process, the record has been downloaded to the offline POC device). Second, a patient can be recertified to the same program of care. Third, an indication can be made that the patient has been transferred to another Agency facility (such as when the patient changes location of residence).

If the patient is transferred to an Inpatient facility, such as occurs when the patient enters the hospital, the associated ProgramAdmission artifact must transition to the Hold state through some status update via the U/I. The artifact should remain in this state until one of the following events occurs:

- Patient is discharged from the hospital, such that the agency can resume the provision of care, in which case the artifact transitions back the Active state.

- The program certification period expires while the patient is in Hold status, resulting in the automatic discharge of the patient from the current program admission (Discharged state).

- The patient moves away or is otherwise transferred out of the service area for the agency, resulting in a discharge of the patient (Discharged state).

- The patient dies while under the current admission to care, causing the transition to the Death state for the ProgramAdmission.
- The watchdog timer around the ProgramAdmission has expired, meaning that the time frame for which the system sets a tolerance for action has been exceeded. In this situation, the system might send a reminder to the Case Manager or Supervisor indicating that the patient's Recertification date is approaching.

Note that the lifecycle allows for "cycling" through different sequences of states, as long as the patient has a valid admission status. The artifact enters a terminal state when the patient either has died or is discharged. As before, if the timeout is exceeded, the timer should be reset and the artifact returned to the originating state.

4.6. The EpisodeOfCare artifact lifecycle

There is a concept of an Episode of Care associated with the admission of a patient into a program of care. It used to be that these two concepts were the same. However, under the new terms of Medicare's PPS payment scheme, the differing characteristics of the episode of care necessitate tracking it in the system with a separate lifecycle. As we mentioned in the previous section, a given ProgramAdmission can have one or more EpisodesOfCare associated with it. Although we won't attempt to enumerate the reasons for this distinction in PPS--as they are documented in the Financial Business Process Specification--we simply present the required state behavior.

Figure 9 depicts the lifecycle for the EpisodeOfCare (EOC) artifact. It has a similar set of state sequences as the ProgramAdmission artifact, with some differences. An instance of this artifact is created at the same time as the associated ProgramAdmission artifact--when the patient was admitted to the program of care. The EOC artifact is initialized into the ActiveEpisode state. While in this state, users may edit patient data, create new encounters (i.e., visits) with the patient or transfer the patient to another agency within the Home Health enterprise. Note that, up until this point, new PatientEncounter artifacts cannot be created (implying that the New Encounter button in the U/I is disabled).

On entry to this state, a watchdog timer is setup around the Recertification window. There is some question as to whether both the ProgramAdmission and EOC artifacts need to be sensitive to a timer around the same time point. It is likely that only one of the artifact instances needs to set the timer. But both may need to be sensitive to the timer's timeout. This requires further thought during detailed design.

The artifact can transition from ActiveEpisode to CompleteEpisode based on the user indicating that the patient has been discharged, has died, has been recertified, or has had a significant change in his/her condition. These latter two conditions are what define the difference between a ProgramAdmission and an EOC. Specifically, if a patient is recertified after the initial duration for an episode of care (for example, for Medicare PPS, this is 60 days), the episode is complete. In addition, if the clinician deems that the patient's condition has changed considerably from that which was originally assessed--and which formed the basis for the plan of care--then the episode is prematurely terminated (i.e., complete). In both cases, an additional transition would be made from CompleteEpisode to ReplayEpisode, indicating that the current episode of care is to be linked to a new one for the current ProgramAdmission.

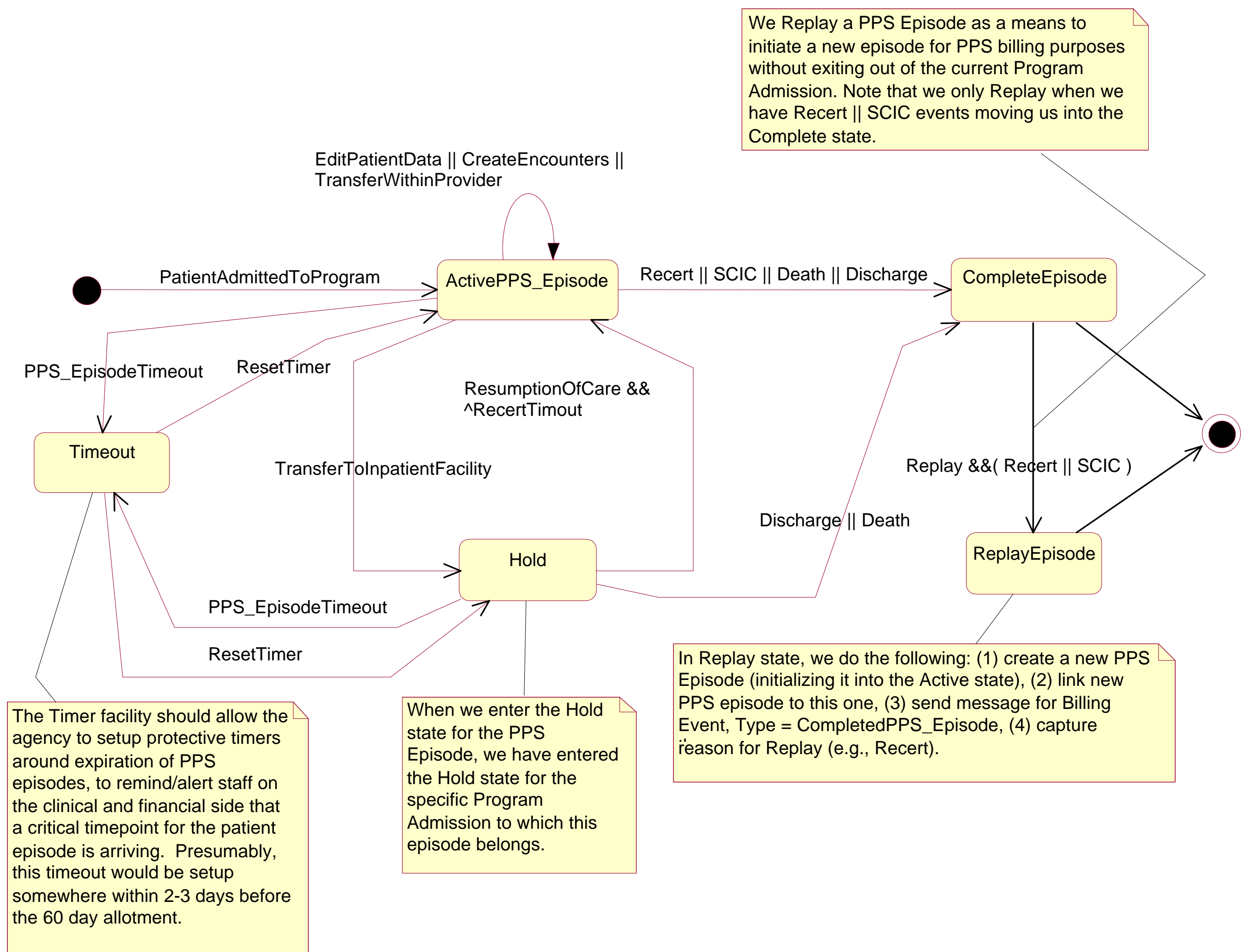

Figure 9. EpisodeOfCare Artifact Lifecycle diagram.

As is the case for the bracketing ProgramAdmission artifact, the EOC artifact can transition to the Hold state by the user indicating through the U/I that the patient has transferred to an Inpatient facility. While in the Hold state, the artifact waits until an event indicating that the patient has been discharged or has died, the patient has resumes receiving care, or the timer has expired. The signaling of the patient having died or been discharged is best signaled by the bracketing ProgramAdmission artifact, since it has more sensitivity to events concerning these conditions.

4.7. The interaction of Intake artifacts

The primary sequencing and coordination of artifacts associated with the Intake process are depicted in the Sequence Diagram depicted in Figure 10. What is important to note is the sequencing of state transitions and how they are causally linked between artifacts. This is only one of potentially many such diagrams that could be drawn up.

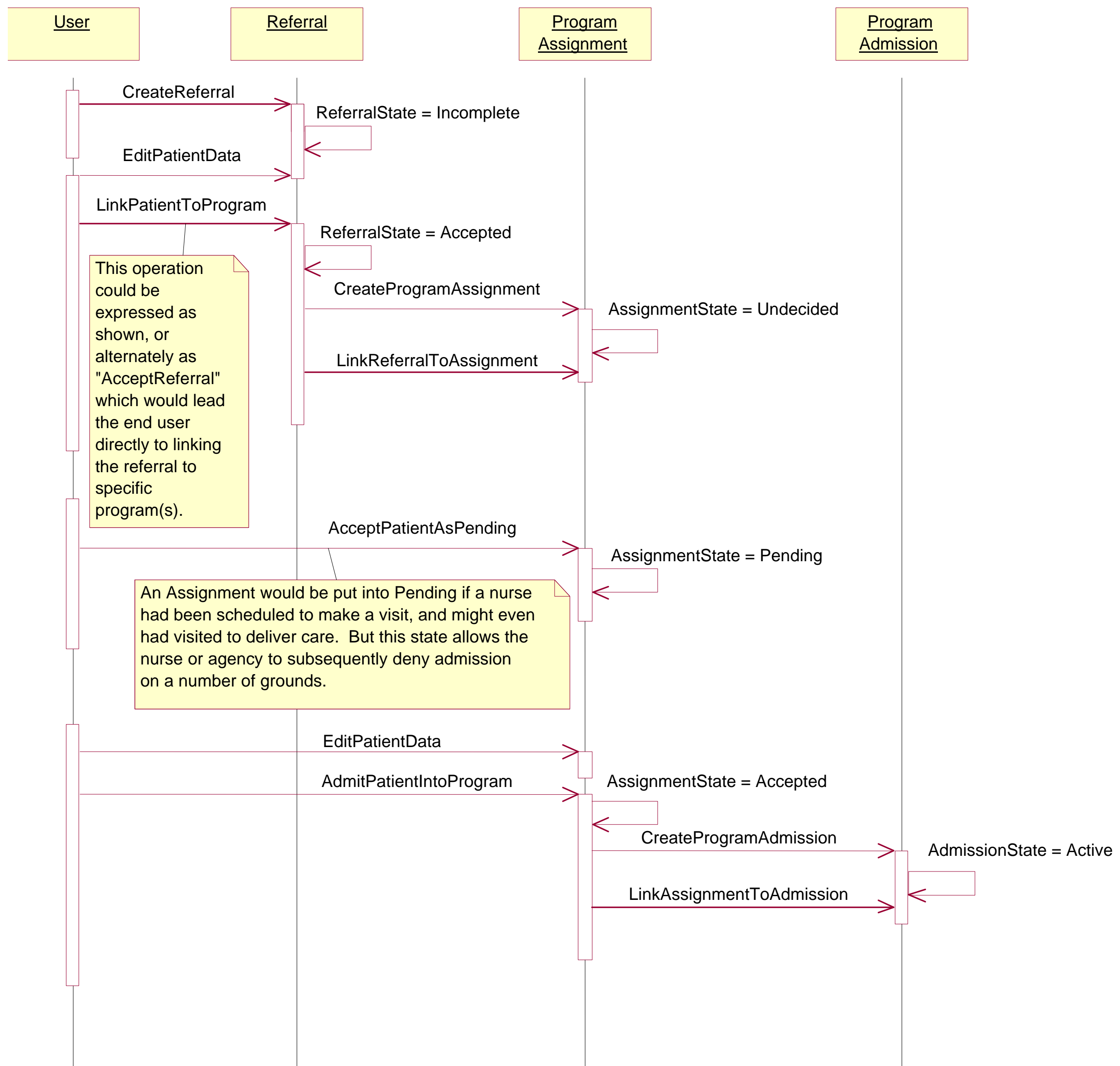

Figure 10. Interaction Model for Intake Artifacts.

5. Summary

This paper presents an analysis method and a design architectural pattern for use in the construction of enterprise-wide workflow applications. Although the direct application of our approach has been in the electronic healthcare, or e-Health, space, we believe it is applicable in any domain where the characteristics of the problem fit the method and architecture.

We also presented an example application of this approach, using the CareCompass™ application that has been deployed in over 300 home health agencies across the country. The methods and architecture described in this workshop paper were conceived based on the development of this product. As such, the example is an incomplete portrayal of the real application, for brevity and confidentiality reasons.

One of the principal tenets of this approach is the separation of the analysis and architectural formulation of the system solution from any consideration of its implementation. It should be noted that the CareCompass system is implemented using a combination of Microsoft technologies, according to their methods for using Microsoft tools, platforms and technologies. However, the system could have been implemented using Java or other commercially available middleware and web development platforms.

One of the principle benefits of this approach is that it is possible to reuse this approach—the analytical methods and architecture pattern—to solve problems in a wide variety of problem domains, where the underlying business processes f the enterprise follow this model. It turns out that there are many such problem domains—both within and outside of healthcare. We are currently examining the use of this approach in other domains, and will be evaluating the benefits of reuse across enterprise applications at such a high-level of abstraction. Furthermore, we will also be examining the logical independence of the architecture from its implementation, to measure how such decoupling allows for the faster construction of enterprise-wide business applications addressing this type of lifecycle-based workflow problem.

6. Acknowledgement

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