AECOS: The Next Generation e-Business Platform

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Business enterprise relies heavily upon information and inter-personal communications. Application platforms for information and communication have largely been separate and distinct. But, recent technologies have enabled the creation of a new dimension of applications that flow from the convergence of the web and phone. The key to harnessing the power of this convergence within the enterprise is a distributed operating platform based upon "universal middleware". The latter enables convenient, powerful, productivity enhancing applications that interbreed enterprise information with enterprise communications. At the same time it provides ubiquitous, universal access from web-browsers, land-line and cellular phones, and the multitude of new wireless devices hitting the market. This paper introduces such an e-Business platform, called AECOS, which enables rapid introduction of diverse functions for distributed applications such as document management, knowledge management, eCRM and contact centers.

1. Introduction

Business revolves around people using information and communications (I&C). Electronic technologies that facilitate the use of I&C have evolved over time, but largely on separate paths -- data applications on computer networks, the phone on the PSTN and private corporate networks. This physical segregation has, to a large extent, kept I&C separate as well. It has even resulted in a *cultural* divide: the phone is commonplace and is used by everyone, while the computer, due its complexity and relative immaturity, is used by a rather exclusive, technically educated, minority.

This state of affairs is currently undergoing a sea change due to the confluence of cheap PCs with the GUI desktop, the Internet, mobile devices such as PDAs, and computer telephony integration (CTI). The GUI desktop has made the computer attractive to children. It is now commonly used in the business and at home. The web is everywhere, distributing information,

games, or whatever else one wants to see. It has led to the invention of the terms “e-Commerce” and “e-Business”.

Even the separation of I&C is becoming blurred. Consider the following increasingly recent developments: fax (a document, i.e., information), is sent over the PSTN (a communication network); e-mail (a message communication) is sent via IP over a LAN or Internet (information networks); a modem connects to the PSTN for web access (to get information, or send and receive e-mail); CTI has led computers (traditionally connected to IP networks) to connect with TDM networks to terminate calls for messaging, or switch voice between TDM and IP (VoIP); cellular phones are as portable and convenient as an address book or “day-timer” (a paper-based schedule and information databases), and the latter are being replaced by little computers called PDAs; “universal port” technology enables “one-number, one-place access” multi-service telephony for voice, fax, modem access.

It is technologies such as those just mentioned that are allowing the paths of I&C to converge. This sets the stage for a greater vision of business I&C – a higher dimension of business functions which combine the web and phone in novel ways. Applications are possible (and are beginning to emerge) that enhance and facilitate collaboration and knowledge management, customer relations and information management, group scheduling and notification, establish communications “presence” and personalized management that limits or facilitates accessibility by phone or message. General features
such as unified presentation and management through desktop style web-presentation, inboxes that collect messages from disparate sources, “one-number, one place” simplicity, and universal (independent of device) and ubiquitous (independent of location) access for communications, information, schedules and notification.

But, are current e-business platforms ready for this vision? Recently Morris Edwards (**Communications News**, *Netcom Update*, Feb. 2001) of IDC, a global IT market research firm out of Framingham MA, recognized that a new e-business platform is needed that better addresses middleware services, data and application integration, and the flexibility of middleware communications. He says, “messaging and middleware are ... vital to the integration of business processes, legacy assets, and disparate platforms, applications and data sources. For e-business applications traditional middleware technologies are inadequate.” According to Mr. Edwards, this new platform, “...would simplify building, deploying and maintaining solutions for e-business, while providing all the functionality required by users”.

Mr. Edward's description is very close to that for an "operating system" (OS). For e-business, the OS must be a powerful, robust, scalable platform. The most cost effective flexible way to accomplish this is with a ***distributed*** operating system. Just as a Windows operating environment enables single host applications to deploy and run easily on a single PC, the distributed OS should enable distributed applications to interact smoothly across multiple computers. The applications might even run across multiple operating systems utilizing multiple protocols, while enabling a wide variety of user devices to interact with new and legacy applications. Furthermore, just as the windows GUI desktop brought the computer to the masses, the distributed platform should make access to new and old distributed enterprise applications familiar, easy to use, even fun.

For this "next generation" OS to satisfy future e-business needs for both I&C, it should provide the wide range of services and accessibility implied by both web and phone. Indeed, "e-business" has been defined as "business that can be done from anywhere, at anytime". We therefore contend that a *full* e-business platform should be based on the convergence of web and phone to provide universal and ubiquitous accessibility that modern business people increasingly require.

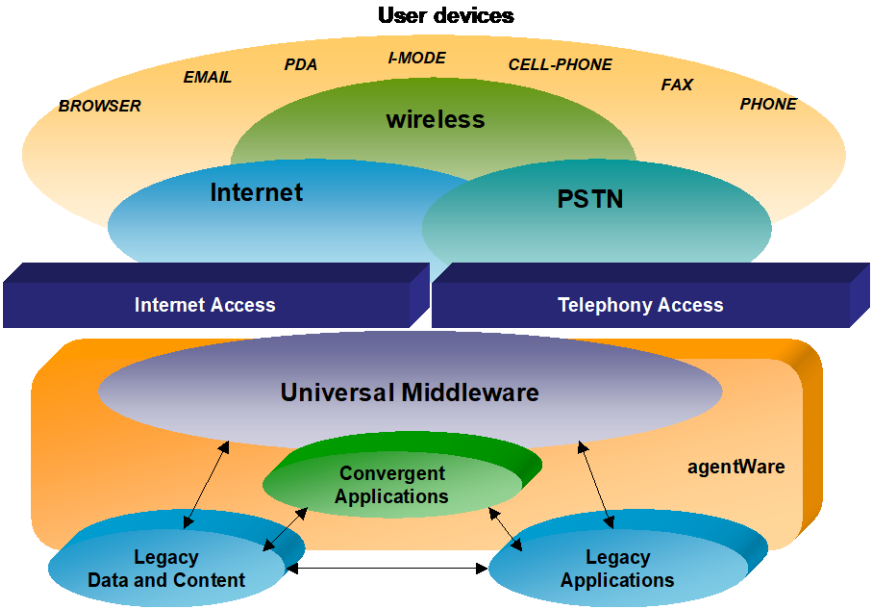


Fig.1 The AECOS platform provides convergence of web (information) and phone (communications) for universal, ubiquitous, user access. Universal Middleware connects and presents a unified view of new distributed convergent applications as well as legacy applications, data and content.

The **A**gile **E**nterprise **C**ontent and **C**ommunications **O**perating **S**ystem (AECOS) ,made by InterLinear Technology, is such a platform (see Fig.1). It enables rapid introduction of diverse functions for distributed applications such as document management, knowledge management, eCRM and others. It provides access to both data and telephony networks using multiple protocols, where telephony access features "universal port" for "one number, one-place" convenience and simplicity. Once established within a corporation for one set of features, other features are easily added. This overcomes the common problems associated with disjoint "stovepipe" systems, each serving an application independently of others.

AECOS provides multi-service, multi-network access to system services for collaboration, transactions, calls, messages, and application integration. These services are distributed, presented and controlled with **"Universal Middleware"** that enables rapid development and deployment of convergent functionality. The glue of universal middleware is the communication layer that exhibits *complimentary modes of request-reply and reliable queues* (see Fig.2), and adaptability to incorporate other modes such as publish and subscribe. Together with re-usable components and proven architectural patterns, this creates a robust, flexible environment for building new, and integrating legacy, applications.

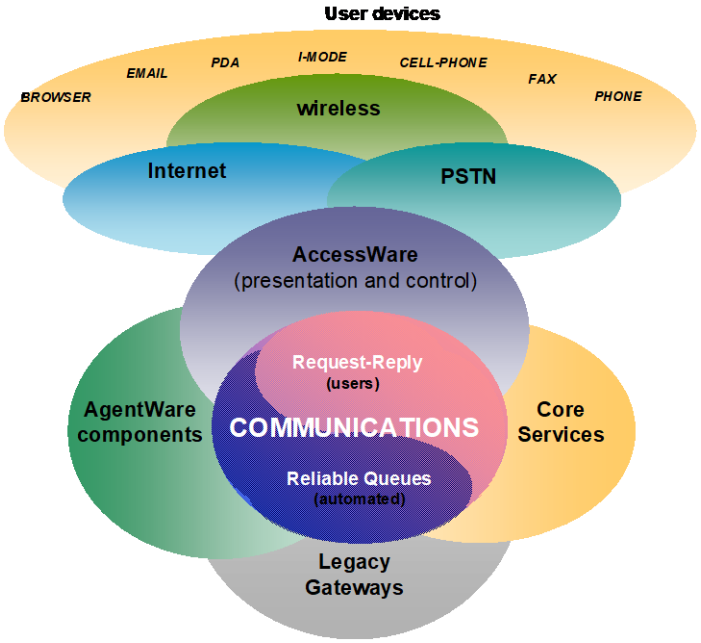


Fig.2 The universal middleware derives power, robustness and flexibility by the complimentary communication modes of request-reply and reliable queues. The former services needs of immediacy of

reply (e.g., user interface responses), the latter the needs of reliability and performance while deferring reply (e.g., communication among automated agents called AgentWare).

The middleware core of AECOS has been implemented for years in mission critical applications such as NASA's Hubble Space Telescope (HST) engineering document repository and information infrastructure in Tokyo Electric Power Utilities (TEPCO). The former was instrumental in the success of the HST repair mission of 1993, enabling wide-area engineering document access and workflow that allowed the space-walking astronauts to "fix the door" that wouldn't close. This history has led to well-tested, reusable modules and communication services which are the foundation of AECOS.

AECOS architecture facilitates applications that are both robust and flexible with incremental scales of deployment for both functionality (over time or personnel) and volume (amount of information and rate of transaction). AECOS can provide access to applications via web-services (e.g., webOS, and multi-device presentation for PC-browsers, i-mode phones and PDAs, SOAP where required), Internet services (such as e-mail, DNS and LDAP), and Telephony services (call management, VoIP and TDM, presentation of IVR with VXML). The webOS presentation style creates a familiar GUI desktop look and feel using a web browser, providing a window into the distributed world.

AECOS can be thought of as a **software orchestra** for an indefinite variety of application "symphonies", built from new or existing models or adding legacy systems (see Fig.3). The operating system architecture has a basic framework – AgentWare, core Services and presentation, access and legacy components, much as an orchestra has strings, brass, woodwinds, percussion. The heart of AECOS is its communications infrastructure, much like the conductor is the heart of the orchestra. Indeed, the conductor is the glue, much like the communications models of Fig.2, that synchronize the music from its parts. Each musician and his or her instrument is like a component in the grand framework. Designing and implementing and application is much like writing music and practicing it – components are used at different times, some not at all for some pieces.

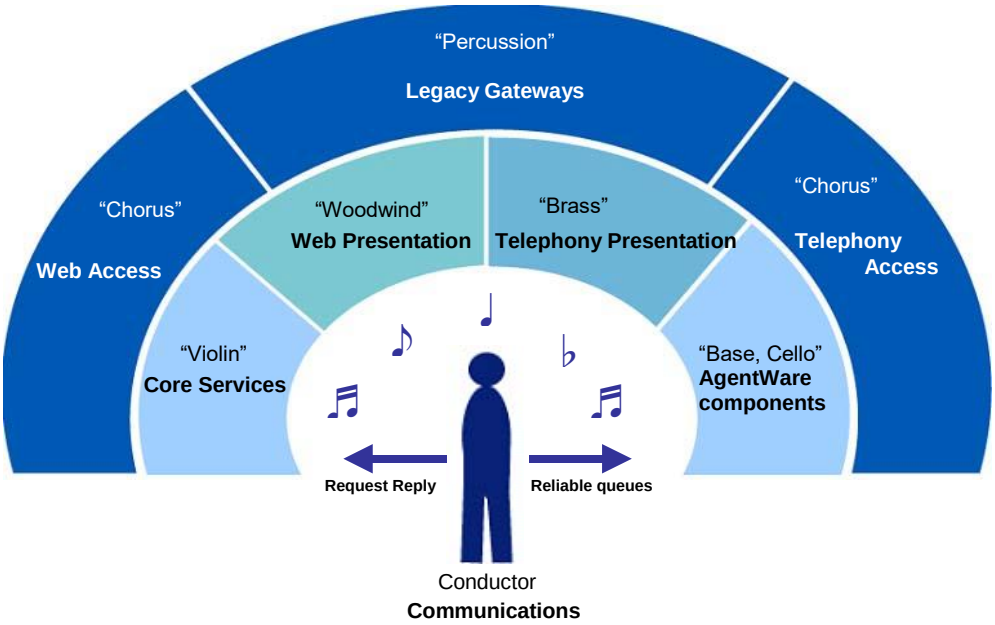


Fig. 3.

AECOS is much like a symphony orchestra, complete with chorus to "sing" in both web and telephony. Middleware products typically provide some features of this picture, and AECOS will use best of breed "raw material" to apply to the appropriate area when appropriate.

Occasionally, special music that requires individual voices, choir, or piano, involves the invitation of musical experts not in the basic form; this is much like legacy applications that are expert in the corporate business operations are integrated to be involved in the desired music.

In section 2.3 we will see how middleware products fit into AECOS, and how AECOS exists in relationship to common middleware platforms. It will become clear what small parts of this picture are really provided by common middleware products, and why AECOS should be thought of as a next generation distributed operating system, not just "middleware".

2. AECOS– the Convergent Operating Platform

2.1. The "3rd wave" – Convergence of the Phone and Web

As stated in the introduction, application platforms for information and communication have largely been separate and distinct (see Fig.4). Telephony voice and fax are transmitted on

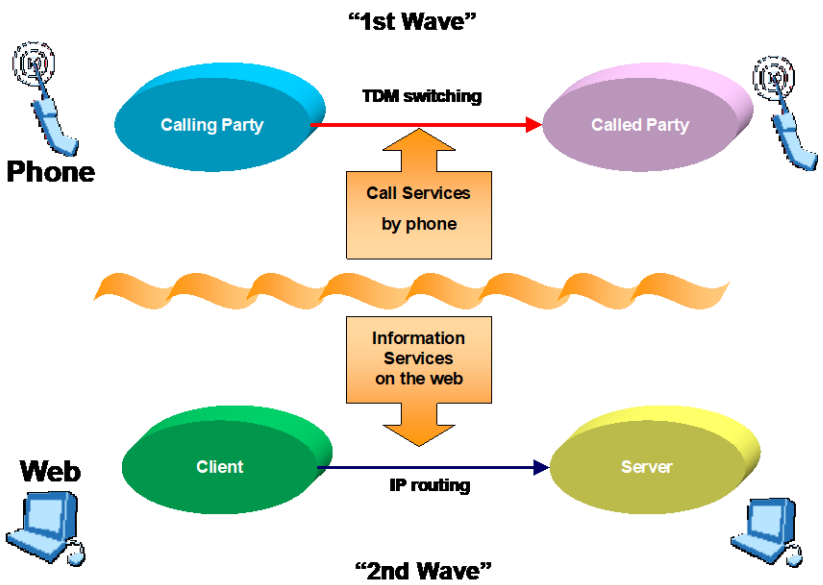


Fig.4 The phone was the 1st wave of communications, the web the 2nd wave. They occupied distinct domains of networks and software. Middleware provided access to call services and information services from their respective networks and service providers.

the PSTN network via TDM (time-division multiplexed) circuit switching. Information is accessed over a packet switched network – typically an IP intranet, extranet or the Internet -- via a browser, or locally using a GUI application with local electronic files. These two types of networks have provided the 1st and 2nd wave of communications and information transfer, respectively.

This segregation of information and communications is not solely because phone and IP networks are distinct. Indeed, everyday people use the PSTN to access the Internet for information and messages through an ISP. But, until recently there has been no access for communications applications to talk with information applications that are available on the web. This is because there has been no common middleware to link access to the two networks – i.e., no "universal middleware". Universal Middleware enables the merging or "convergence" of information and communications applications and networks to yield a 3rd wave of I&C applications (see Fig.5).

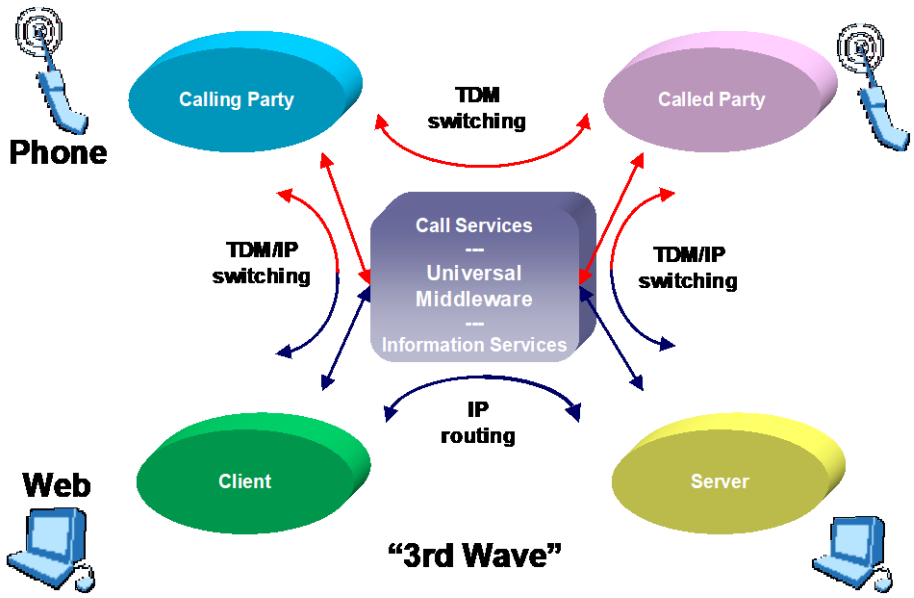


Fig.5 Convergent applications – the 3rd wave -- co-mingle access to telephony and IP networks. This is done through multi-service multi-network connectivity to Universal Middleware. This enables the cross-fertilization of telephony communications with information and IP-messaging applications.

As Fig. 5 implies, call services may be multi-service in nature so that voice over TDM may be switched to TDM or VoIP, fax may be detected and terminated to save an electronic document, or switched out to a fax machine, or modem may be switched to a modem bank for Internet access. Call management may access presence or service information based upon information managed or personalized from a web interface. Messages may be composed on the web, then broadcast out not only as e-mail but also as fax or phone messages – Active Messages™ and interActive Calls™.

2.2. AECOS Architecture

AECOS is a multi-tiered architecture consisting of 3 basic layers: access, data and middleware (see Fig.6).

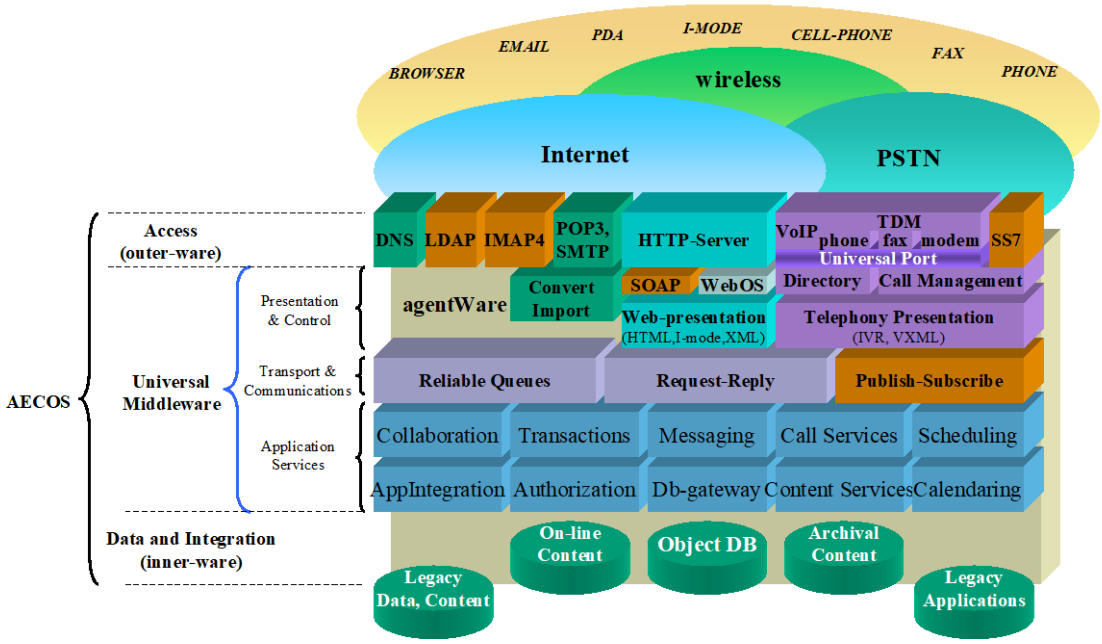


Fig.6 AECOS exists in three basic tiers – access, universal middleware, and data storage – "immersed in" or supported by "agentWare". "agentWare" performs various automated agents that perform specific, usually asynchronous, information or message management services.

The outermost layer is the access layer. It is the "skin" and "senses" of the platform. It connects AECOS to the Internet and Telephony networks through industry or international standards and protocols. It provides multi-service, multi-network access to mobile, PC and land-phone devices. Multiple protocol services such as DNS, e-mail (SMTP, POP3, IMAP4), HTTP and LDAP, all over IP, reside here. Telephony interfaces, using universal port technology, also resides here. It services voice for TDM (PSTN and cellular), fax, and modem, all at "one-number, one-place". It also services voice for messaging (inbound voice-mail, outbound active Messages or interActive calls, text-to-speech [TTS] for playing e-mail or text) and VoIP. Such services as automatic speech recognition (ASR) and address resolution (ARS) along with call management are features

of control. Additionally, SS7 signaling services for call-set up interactions with Telco switches may be required and will also reside in this layer.

The innermost layer is the data layer where information structure and meaning is maintained. It is the operating system's "short and long term memory", and layers on top of 3rd party databases, local file management and operating systems utilities. It provides database services, data location and archive services. It is also the legacy layer where existing enterprise applications, data and content can be integrated.

In the middle is "universal middleware". It is like the nerves and the brain of AECOS. It enables the user to talk to the back end and distributed modules to talk to each other. It provides the logic of applications that are deployed. It also provides presentation and control for navigating functions, and the capability to integrate legacy data, content and applications. At its core is AEDIS – the middleware technology used to build aforementioned information infrastructures such as NASA's Hubble Space Telescope Repository, Samsung F16 fighter construction management, and Tokyo Electric Power Utilities. AEDIS includes application generator software that builds application service components and a base data model from a point-and-click GUI. This enables system development to "start near the finish line".

The universal middleware itself consists of 3 layers: the presentation and control, transport and communications, and data and integration.

The presentation and control layer is the "persona" of AECOS. It determines how the system is seen and heard, what functions it makes available, and how functionality unfolds to the users, administrators and external software that may interact through, say, SOAP. "webOS" offers the web user a "window into the distributed world" of AECOS. It presents a windows desktop like look and feel where "icons" represent functions or business tools such as "Inbox", "Address Book", "Calendar", "Web-Collaboration", "Active Messaging", "InterActive Call", and so on. It also controls and authorizes the use of the features per subscriber. Telephony services presents familiar "IVR" (using VXML, for example), text-to-speech, and performs ASR (speech recognition) or DTMF for user commands.

The transport and communications layer moves data and information between applications, system services, and between layers. At its heart it is made primarily of two complimentary models of distributed communications: request-reply and reliable queues (see Figs 2,6).

Request-reply is a “wait for response” model for immediate results. It is an “immediate” mode used primarily for user transactions, or any automated agent (i.e., agentWare) or other process that demands immediate action. Reliable queues are asynchronous “drop work and leave”. This “deferred” mode is used primarily between agentWare components to move and process content. It may be appropriate to use other models such “publish-subscribe” if desired for future applications.

The application services layer is the cerebral cortex; it determines the logic of specific functions, and will access the memory (i.e., data sources) when needed to carry out those functions. It provides the logic for such services as transaction management, collaboration, calendaring, scheduling, messaging, call services, authorization, and database gateway. It also provides application integration hooks through APIs.

Underlying this multi-tiered architecture is “agentWare”. It is like the circulatory system and organs. It processes input, makes sure it gets converted to the right format and gets to the right place for AECOS to use. It also provides services like scheduling, data backup, broadcast service updating, out-bound messaging. It is commonly based on reliable queues as they are automated services that may defer their action once a requestor delivers an action object.

2.3. AECOS in relation to existing middleware products

It is important to understand AECOS and “universal middleware” in relation to other middleware products. The “software orchestra” analogy used to describe AECOS in the introduction is very helpful for this discussion. Consider Fig.7. AECOS comes complete with a default set of ready made components (musicians, instruments) within the orchestral framework (distributed operating platform). Systems may be built right out of the box, much as one can have an orchestra play some familiar tunes quickly. Furthermore, the full range of accessibility to the audience is provided by both internet and telephony access, control and presentation.

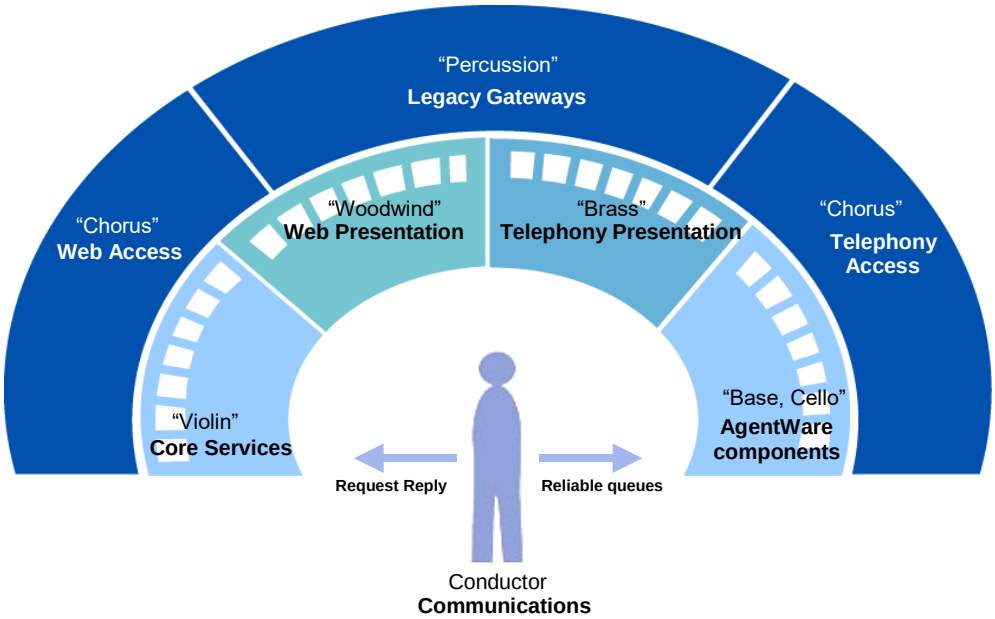
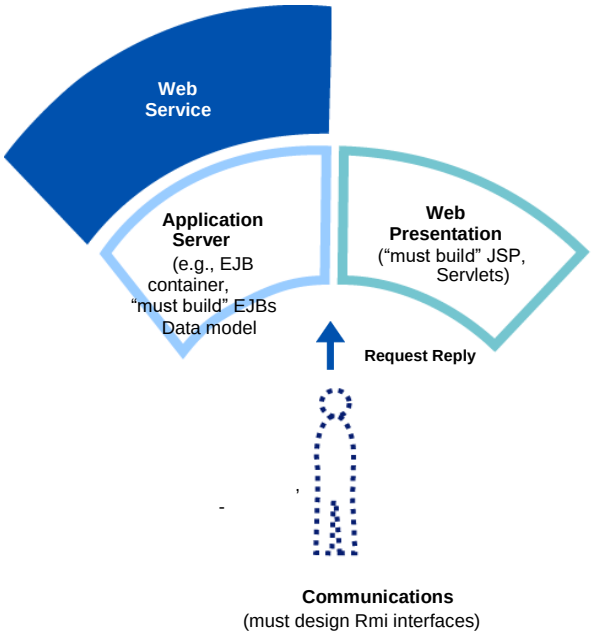
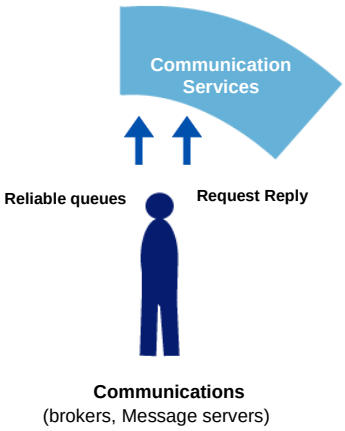


Fig.7. AECOS, "application generator" fills the core services with musicians that provide basic services for common user needs. It is also a springboard that enables feature developers to "start near the finish line", i.e., to develop applications fast. Note that certain seats( ) may b eft empty, implying that isolated customization or components may be added to the core-services, agentWare or presentation layers as required by new or custom functions. Also, legacy gateways are available for database integration and data mining, or legacy content.



(A) Java Application Server



(B) CORBA, MQseries

Fig.8 Contrast Fig.7 to these "orchestral depictions" of common middleware product offerings: (A) Java Application Servers (EJB containers of BEA WebLogic, IBM Web-Sphere) and (B) message brokers (IONA-CORBA) and message queues (JMS, IBM-MQseries). In (A), web services are fully available out of the box, although SMTP, DNS, pop or IMAP may not be; the application server itself is just a container – few if any EJBs are given. Although some java communications services are available (like JNDI) communications interfaces must be specified, servlets built, EJBs built and data model designed and built. (B) Rich communications services are offered by CORBA and MQseries products. The latter is a reliable queue technology. This may satisfy a part of the AECOS picture when appropriate for speed, performance, or application integration with other MQseries products.

The image of Fig.7 should be contrasted with that of Fig.8. In the latter, pieces are available in typical middleware offerings, but they are only small parts of the picture. Often pieces fit very well into the AECOS distributed platform, and best of breed will be used where cost, performance and reliability make sense relative to default AECOS components and communications pipes.

Thus, AECOS is more than the form or orchestral seating arrangement. On the other hand, a java servlet engine or java Application server *would* be just seating arrangements – providing the container and management framework, but not the components as they must be built. AECOS, on the other hand, by default is filled with expert musicians in every domain of the orchestra, with fine musical instruments. AECOS is thereby differentiated from most middleware products that yield only a section of empty chairs (e.g., containers) a few musicians (components) or a conductor (communications infrastructure) with some communications services, or possibly a score (a design for an application). Very important, AECOS provides the full telephony convergence – the full orchestral compliment -- that the next generation e-business platform must have.

Consider now the more technical picture of the AECOS shown in Fig.9 below. The universal middleware is an architectural layer on top of typical middleware components and third party offerings. It is essentially AEDIS (Agile Electronic Distributed Information Solution, mentioned in the previous section) consisting of core services, reusable agentWare components, application

generator for middle-tier logic and data model, and architectural design patterns that enable rapid development of robust applications and middleware.

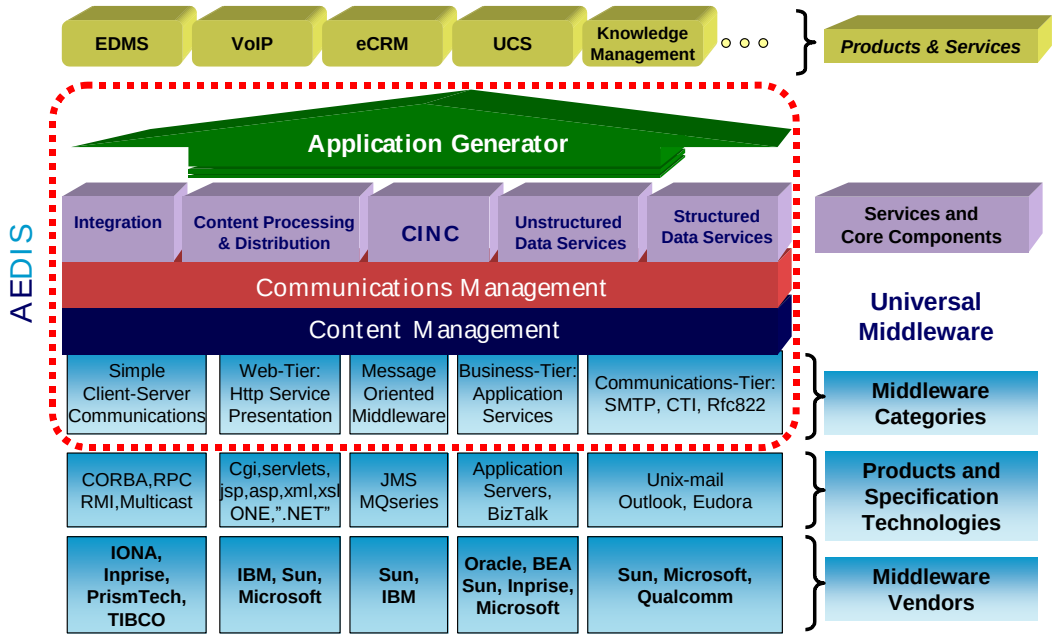


Fig.9 The foundation of AECOS is AEDIS – universal middleware and application generator functions. It is a higher level of abstraction than other middleware products. AEDIS has its own It may use Best of Breed products as components of a solution if required.

Together they constitute architectural "moulds" or "templates" for RAD. The desired application determines how the moulds are put together, and what shape they take, just as a mould for the shape of a car fender or engine block determines the differences in look and function from model to model, year to year. Turning the production line on quickly yields new products and services.

Thus, AECOS uses typical middleware components, like application servers, transport and communications, transaction products, as raw materials to be poured into these moulds where and when appropriate according to objectives such as cost, performance, and speed of development. If Best of Breed is appropriate in cost, then it may be used; otherwise, native AEDIS and AECOS software is used. For example, AEDIS utilizes a mixture of ONC-RPC and reliable queueing for transport and communications. It could easily incorporate CORBA or publish and subscribe service such as JMS where appropriate; the cost vs. functionality has not justified their use in applications developed until now, but may be justified in the future. MQ-series utilizes reliable queues, and might find use within AECOS especially it is necessary to integrate MQ-series applications. MQ-series provides simply another way of communications

among modules for closer to real-time behavior, in addition to simpler to implement, but somewhat slower, reliable queues of AEDIS.

AECOS currently uses an application server that is compiled by an application generator to run on Unix or NT. Its high performance scales well compared to java application servers such as IBM's WebSphere, BEA's WebLogic, or Sun's iPlanet server, because the AECOS application server does not depend on java or JDBC, both of which slow performance significantly below more direct CLI interfaces that Oracle, for example, provides. However, such component based approaches may be appropriate or desirable, especially if, for example, special EJBs have been developed and it is desired that they be reused in AECOS. If so, one of the java application servers could be used to develop an EJB component based service, and it would fit into the architecture of AECOS to augment its normal application server. The transport layer would be RMI request-reply, probably from an http presentation layer provided by a Tomcat servlet engine (or within the application server itself).

In the previous examples, the use of 3rd party software may be appropriate, but there is always a cost of licensing the product. Furthermore, although a component approach sounds nice, components have to be built. AEDIS implementations begin by using an application generator that produces an application server module (the middle-tier) and a database instance. This takes care of functions most commonly used in an application. Additional features may be directly programmed as functions in the middle-tier and the database, or as agentWare that "wraps around" core application services.

This highly flexible model of development yields rapid solutions. The same code that is used for one EDMS can rapidly deploy in another, with new user defined classes of content management and data handling. This is especially useful in projects that need rapid to immediate deployment. Of course, full customization often involves presentation layer modification or application integration, but custom code is typically isolated at the middle-tier or presentation layers, leaving most core services to be simply reused.

2.4. Multi-network, Multi-protocol, Multi-service Access – convergence and ubiquity

How does AECOS provide “ubiquitous, universal accessibility” and convergence? The answer is intelligent coordination of multi-network, multi-protocol access by universal middleware. Consider e-mail. If e-mail is desired from a PC, a mail application with Internet connection will do. But on the road with only a cell-phone, a connection to a wireless network (through the PSTN, say) is required. But that’s not enough. One cannot hear text. So a text-to-speech presentation is required. Furthermore, the data and message content must be accessible, possibly from a remote telephony server point-of-presence. This requires middleware to get a user request from the access layer down to the data layer and push the information back out to the access layer for delivery. This provides everywhere presence. That is ubiquity.

Convergence is further illustrated as follows. The phone can be used to hear e-mail, and can also deliver a fax from a fax machine to a user’s inbox. That inbox may be viewed over IP by web-browser or PDA. The fax can then be displayed or forwarded to a fax machine from web, PDA or phone. The fax could even be analyzed by optical character recognition (OCR) for a TTS rendition over the phone. The application could even receive incoming calls for voice-mail that could be accessed from the phone, forwarded out to an e-mail location. And so on.

But, how about universality (i.e., device independence)? With a PDA, for example, a wireless connection through the Internet can access e-mail through HTTP and message services. But a normal web-browser format is insufficient. Control must decide what device so the presentation will be appropriate. Then the middleware enables access and transport of the content from the data layer through the access layer to the device in the appropriate format. Then, it can be delivered as HTML to a PC web-browser, cHTML to an i-mode phone, other various versions of HTML to iPAQ, Palm or J-Sky PDAs, WML to WAP phones, then POP3 or IMAP to respective e-mail clients.

Indeed, if necessary, AECOS can receive a request over one network and invoke an application service that responds to the requestor in another network! Such an application can yield competitive advantages in certain circumstances.

Consider again the picture of AECOS in Fig.6. The access layer provides connectivity to multiple networks, and multiple protocols per network. An IP network connectivity provides an interface to HTTP, e-mail protocols such as SMTP, POP3 or IMAP, and directory services such as DNS or

LDAP. H.323 connectivity is also provided for VoIP call set-up and connection. Telephony connectivity is provided by the telephony server for both VoIP and TDM payloads. “universal port” technology enables single port delivery of fax, voice or modem. At call setup time, connection management will discern the payload or signal type and perform the appropriate switching or termination at that time.

The list goes on. The web makes personalization of telephony services as easy to configure as “point-and-click”. Changing phone-numbers in a follow-me service is simple; so is configuring call screening or filtering, prioritizing incoming calls by caller id (“connect me if its my boss – take a message otherwise”) or e-mail “from” address. No waiting for the phone service, no incomprehensible key-pad number sequence.

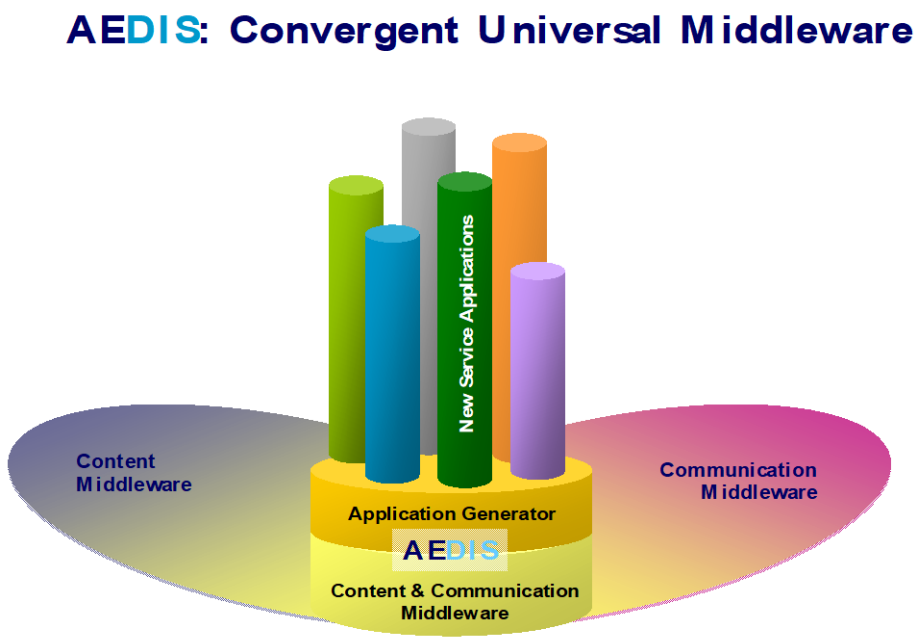


Fig.10 Content middleware, combined with communications middleware yield a new dimension of applications. Application generator technology facilitates rapid building and deployment. The universal middleware is called AEDIS (Agile Electronic Distributed Information Solution).

Thus, AECOS provides ubiquitous, universal accessibility to applications by converging information and communications, the web and the phone, on a distributed platform. It yields a new dimension of application much like two stereoscopic images superimposed yield depth perception (see Fig.10).

2.5. Multi-Service Access – convenience and simplicity

Multi-service access applies to what services or protocols are available over this telephony circuit at this phone number, or what services are available at a given “url” on the web. The “universal port” is an example of this. ILT’s patented universal port for telephony implies the system will detect a fax, voice, modem or data payload at the “same number”. So, an application can decide what to do with each as it arrives – separate circuits do not have to be “reserved” per payload type. This also implies the same telephone number may be used as one’s fax number, and in principle, as one’s ISP number if that service is offered. This is the meaning of *one-number* in the phrase “one-number, one-place” technology.

It is now possible to manage personal communications on via a web interface, such that a phone call or fax will reach you where you are based upon a device of your choosing. A phone application will be able to establish via your “presence” a means of either web or PSTN communication, real-time or message oriented, all at a user’s point-and-click command. Furthermore, data packet networks can now carry voice (e.g., VoIP and VoATM) as well as data.

Services can now be built that enable a phone user to “hear e-mail”, transfer documents or print them to a local fax machine. It also enables a “universal port” – one-number, one-place for phone, fax, and data, so that a fax may automatically be detected and dropped into an e-mail inbox, or a phone call routed to the appropriate number. A PC user can initiate a phone call using a web-browser plug-in or PC application via VoIP, and a switching service can follow a called party to his presence on a PC, or to a cellular phone, or simply take a message if the calling party is identified by the called party’s service (as the called user configured it by the web) as “not-urgent”.

3. Removing the barrier to acceptance through AECOS

The AECOS approach is to provide access to a minimal set of convergent features and applications through familiar phone, messaging, and desktop paradigms. Out of the box it provides distributed solutions for the predominant 20% of functions used 80% of the time. Web-collaboration tools are generic, enabling such applications as group sharing of electronic document libraries to simple knowledge management. More sophisticated features as data-mining may require systems integration within the corporation which may be added as needed or desired with customization.

There have been attempts to deploy converged applications such as customer relations management (CRM). But the failure rate is high – upwards of 65%. The complaint is the failure of the application to integrate well into the corporate culture. For example, interfaces were hard to use, navigation of the application difficult, and communications integration awkward or difficult.

For applications to gain acceptance, a familiar paradigm of use must be available. At the PC, a web-browser paradigm has become most familiar, at the phone interactive voice response (IVR). Furthermore, the “unbundled” nature of the PC “desk-top” has proven its success, even among children. AECOS presentation is formulated with this in mind.

AECOS provides content and communication features in a visual manner through a web-browser based “desktop operating system”. It un-bundles the functionality of converged applications. Thus, simple features like “inbox” and “folders” for messages, “active” and “interactive” messaging for scheduled notification and notification with feedback, personal and group calendars, personal and group documents, are available via the visual “icon on a desktop”, but presented within a browser. The latter implies that functions can be introduced, authorized, and used one-by-one, as needed.