Global Information Architectures: Alternatives and Tradeoffs

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Abstract:
The alignment of information architectures with business strategies is important for organizations in order to achieve global pre-eminence. Past architectures have been limited in that they consider only technical and computer-based aspects of information technology. This article broadens this view by including the functional aspects (data, voice, image, or video transmission) of information technologies. Five information architectures emerge as feasible for global corporations. Examples of companies using these architectures are provided. These architectures are further compared using cost variables. The article provides a means for researchers and managers to classify and evaluate the current architectures used in global corporations, and help carefully plan future architectures.

Article:
Introduction
Globalization of companies has increased the need to design information systems that help a company compete effectively in the global market.[1] Effective implementation of information architectures on a global scale can compress time and space and permit sharing of scarce corporate expertise. The alignment of these information architectures with global business strategies is important in achieving global pre-eminence.[2]

While the importance of strategic fit is emphasized, the information architectures used in these literatures are not focused towards capturing the extensive deployment, management, and control of information technology. To cite some other works, Malone[3] uses four generic coordination structures to model information processing involved in organizations and markets. Leifer4 classifies computer-based information systems as centralized, distributed, decentralized, and stand-alone systems. Tavakolian[5] uses the locus of responsibilities for information systems as an indicator of information technology structure. Ives and Jarvenpaa[6] classify global information technology architectures as independent, headquarters-driven, intellectual cooperations, and integrated. Morison[7] emphasizes the need to coordinate and control business-critical systems using virtual centralization. These literatures are limited in considering only data communications and do not include other and future information technology possibilities.

The contribution of this article is to propose information architectures that capture the richness of the current and future information technologies. In addition, the proposed information architectures are expected to be of use over a longer period since they describe functional (data, voice, text, image, and video transmission) aspects of technologies rather than particular technical aspects of technologies. The article, in addition, discusses the tradeoffs in choosing among the architectures using production, coordination, and vulnerability costs.

We propose this architecture in the context of global information systems, although it is generic enough to be applicable to multi-divisional domestic information systems operations. We do not consider the case of a small organization where all business operations are centralized and there is no need for a network.

Elements of information architecture

Prior literature has been limited in identifying only computer-based information systems as part of an information architecture. Karimi and Konsynski[8] identify the key components of a global information systems architecture as: (1) a centralized and/or coordinated business/ technology strategy based on establishing data communications architectures and standards, and (2) a centralized and/or coordinated data management strategy for the creation of corporate databases. Similarly, Leifer[9] constraints his strategic fit discussion to computer-based information systems. These discussions constrain the information architectures to data communications and leaves out the importance of voice, facsimile, and video transmission to an organization. Integration of these information technologies is a worldwide trend and firms who fail to build voice, data, facsimile, and video bridges would be increasingly at a competitive disadvantage.[10]

We are taking a broader perspective in this paper beyond the well recognized and studied computer based information systems of an organization. That is we look at information transmitted through phone, fax machines and possibly even a video conference. We are interested in the functional aspects (data, voice, text, image, or video transmission) of information technologies rather than particular forms of technologies as they exist today. In that way the information architectures we define here will have use over a longer period. Note that an information architecture will show the connections among the devices, media, equipment, software, and networks used by an organization to transmit voice, data, text, video and images between end-users.

We use three elements to generalize the extensive equipment, networks, and software used to connect users in an organization. These elements are: user interface devices (UID), information processing, transmission, and storage systems (IPTS), and information management and control systems (IMCS).

User interface devices (UID) are used by an end-user in accessing current information or creating new information. Examples of UID are phones, microcomputers, terminals, data entry devices, and printers used by end-users in an organization.

Information processing, transmission, and storage systems (IPTS) are intermediate systems used by the end-users. Thus we are considering all media that process, transmit, or store information among multiple end-users. Examples of IPTS are public branch exchanges (PBXs), data base management systems (DBMSs), front end processors (FEPs), cluster controllers, routers, gateways, mainframes, minicomputers, multiplexers, network servers, etc.

Information management and control systems (IMCS) manage and control the information technology function performed by UID and IPTS. Examples of IMCS are: management software for control of mainframes and switches, control systems of database management systems, control systems of gateways for connecting to dissimilar systems, network management systems of physical telecommunications networks, management systems of multiplexers etc.

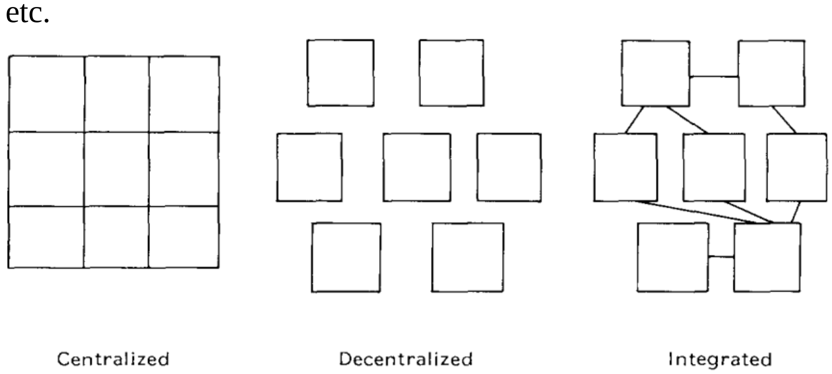

Figure 1. Architectural configurations

Element configurations

Each element of the information architecture can be configured in three to four ways depending on a particular organization. Bajwa, Chaudhuri and Ramaprasad[11] identify the possible configurations as simple, functional, divisional, and matrix. Karimi and Konsynski[12] identify the configurations as decentralized, centralized, or integrated. We adopted the Karimi and Konsynski classification of centralization, decentralization, and integration.

In order to define these possible configurations, the concept of logical versus physical connectivity needs to be clarified. Physical connectivity is what it implies; whether the parts of an element are physically together in the same building/complex or in separate locations. Logical connectivity means that a telecommunications network connects the parts of an element so that the connections are transparent to the user.

In a decentralized system, elements are physically separate and logically disconnected. In an integrated system the elements are physically separate but they are logically connected. In a centralized system the elements are physically together and are logically connected. For example, international telephone networks are an integrated system since the caller and the called party are logically connected, although the parts of network are physically separate by thousands of miles. Figure 1 illustrates these configurations.

In a large organization, the UID have to be integrated in order for the end-users to be able to communicate with other users. A decentralized UID will imply that end-users do not have any logical connectivity to the information processing, storage, and communications resources of an organization. It is difficult to be effective in an organization with such isolated usage. A centralized UID will imply that all end-users have to be physically together which also does not apply in a global corporation. Thus only the 'integrated' option for UID is meaningful for large organizations.

The IPTS can assume any of the three configurations of decentralized, integrated, or centralized form. Decentralized IPTS means that the physical resources such as PBX, multiplexers, networks, database management systems, and computers are separate and are logically disconnected. Integrated IPTS implies that these resources may be physically separate, but, are logically connected using telecommunications networks. Centralized IPTS means that the resources are physically together in a central location and are logically connected.

The IMCS could also assume decentralized, integrated, or centralized configuration. Decentralized IMCS means that information technologies at separate divisions are managed independently. In an integrated IMCS, the management systems of the components are logically connected together and the physical control is left to the discretion of where the management wants the control to be. A centralized IMCS means that all the control system are connected together and managed centrally.

IPTS \ IMCS	Centralized	Decentralized	Integrated
Centralized	Architecture 1	Inappropriate	Architecture 4
Decentralized	Infeasible	Architecture 2	Infeasible
Integrated	Architecture 5	Inappropriate	Architecture 3

Figure 2. Information architecture alternatives

Information architecture configurations

Information architecture specifies the possible ways to combine the three elements using variations in their individual configurations. We need to consider nine information architecture configurations, since the possible configurations among the elements are: UID one, IPTS three, and IMCS three.

Figure 2 shows the nine possible architectures among the IPTS and IMCS elements. Two possibilities are infeasible and two are very expensive for the organization. The remaining five possibilities are either feasible and/or appropriate. Among these, three architectures (1, 2 and 3) represent an ideal match between IMCS and IPTS.

Two architectures are infeasible. When IPTS is decentralized, then it is technically not possible to manage the systems (IMCS) either in an integrated or centralized manner. A simile may help: an IPTS may be likened to the operations at a battlefield; the IMCS is the command and control centre. If the operations at the battlefield are physically separate and logically disconnected (decentralized), there is no way to command and control the war in an integrated or centralized manner. Therefore these two alternatives are 'infeasible'.

Another two inappropriate architectures arise when IMCS are decentralized due to management reasons. It is then extremely expensive to centralize or integrate the IPTS. Once resources are spent to centralize or integrate IPTS, it will take only marginal resources to centralize or integrate IMCS. Hence, these two options are 'inappropriate'.

Thus, in all, five architectures are worth pursuing. These are discussed next.

Centralized IMCS, centralized IPTS

In this architecture, all the information resources are centrally located and controlled, and data as well as non-data (e.g., voice, image, video) access is made via the central resources. Banks[13] are examples of organizations which use this architecture to manage their data re-sources. Specifically, a Canadian bank has concentrated its database management systems, data processing systems, and network management systems in Canada, though the bank has offices requiring user interfaces in Europe, the US, the Far East, and the Southern Hemisphere. Though bank staff around the world can use the products of the bank, customization of products by bank staff is discouraged unless required to meet business requirements such as security protection.

The bank employs a centralized data processing philosophy to allow for economies of scale and efficient amalgamation of information systems. The central computing facilities are physically located together. The network is managed through an automated operations system located at the central computer centre. The bank uses IBM's Netview and network management systems from NET Multiplexers to provide up-to-date information on network performance.

Another progressive company using this architecture is Federal Express. Federal Express is in the overnight (and two-day) delivery business and has thousands of offices/points of contact with customers. According to a Federal Express executive,[14] coordination and control of such massively distributed sites is conceivable only through a highly centralized system of computers and associated equipment. Among other applications, this centralized system hosts Federal Express's international package-tracking COSMOS application, well-known for its strategic implications. Federal Express's computers and other technology resources (IPTS in our terminology) are located in Memphis and are tightly managed from there.

Companies using this architecture expect such a setup to relieve a great deal of the vertical pressure (communication flow from top to bottom and bottom to top) from an organization, and let the operators focus on providing services to end users. They expect this to have a unifying and possible simplifying influence on the organization. Upper management at such companies believe that a centralized IPTS and IMCS will simplify internal management by maintaining a clear hierarchy. They expect such a comprehensive centralized plan not only to be the agent of success, but an effective communication process.[15]

Decentralized IMCS, decentralized IPTS

Companies using this architecture are decentralized and use separate systems and staff to manage their diverse IPTS. Again, the companies using this option may be able to process not only data, but also voice, video and image traffic through these decentralized operations.

Generally, this architectural strategy is a direct consequence of the 'decentralized' business strategy of the organization. While companies may pursue a decentralized strategy for various reasons, conglomerates (e.g., TEXTRON and LTV Corporation) and holding companies almost do not have any other choice due to the heterogeneity of their business. Such companies tend to use the decentralized IT architecture option. On an international level, companies, using the multinational international strategy[16] of having autonomous subsidiaries in foreign countries, will again use the decentralized architecture. As an example, Trafalgar House plc, a commercial and residential property development conglomerate based in London[17] does not have an overall information systems strategy (i.e., the lack of centralized or integrated IMCS), and its IS divisions (i.e., IPTS) are decentralized at the divisional level. The central IS group acts only in an advisory capacity.

Another example, closer to home for us, is the data-oriented activities in universities that have many different colleges/departments. Each department/college may order and implement its own IPTS. Frequently, individual faculty members will implement, manage, and control their own computer hardware and software. In such a setting, the university computing services or telecommunications services will have very little control or management responsibility for the department/college/faculty member's IPTS.[18]

Integrated IMCS, integrated IPTS

This architecture implies that both the IPTS and IMCS are integrated together. A central management and control division could optimize the network and build backbone networks so that the traffic of the divisions can be routed on that. General Electric Corporation (GEC) has integrated the voice, data, and video traffic on their subsidiaries by creating an information technology division. This division has created backbone networks of high capacity connecting major cities around the world and contracts its services to the various divisions of GEC. Individual divisions lease part of the backbone network to provide information services to their employees. Integrating the network has provided significant cost and efficiency benefits to GEC.[19] The backbone networks are managed using integrated management and control centres. The integrated IMCS collects information about the division networks and can control and monitor them carefully.

Centralized IPTS, integrated IMCS

This architecture evolves when a company starts moving away from a single vendor centralized IPTS solution. The rapid increase in end-user computing has made this architecture essential in those companies that are forced to support multiple vendors for UID, but still like to retain control and management of the UID and IPTS. In these cases, the UID may use multiple media and are connected to the central mainframe and other central IPTS. Then, the management systems for different UID media differ and these management systems have to be integrated together to provide integrated management and control of the UID and IPTS.

An example of this architecture is the voice communication systems deployed by large telephone companies. They may use switches, multiplexers, and cables produced by their subsidiaries and centralize them in their central offices to offer private service offerings to customers. But, the IMCS for these systems may be different due to the technical differences in the divisions that manufactured the devices. Then, special IMCS need to be developed and the parts of IPTS have to be integrated to provide management and control of the information resources.

Centralized IMCS, integrated IPTS

This architecture provides distributed operations, but with centralized monitoring and control. American Express is a good example. Different divisions of the corporation do not compete for the same customer's business. While American Express controls its network centrally from its command post in Phoenix, AZ, the scope of the American Express Travel Related Services (TRS) Co network extends worldwide.[20] The company serves its clients online 24 hours a day in more than 200 US cities and 125 countries around the world. Along with TRS's internal users, the network supports such outside clients as airlines, travel providers, retail establishments that honour American Express charge cards, major corporate card accounts and credit bureaus.

The company's integrated telecommunications network (ITN) is made up of 35 switching hubs, or nodes, around the world. The equipment in those nodes are IBM front-end processors. The design objective for the network is to connect any terminal to any data host, if authorized. Any discussion about what could be connected to the network starts with 'Is it SNA compatible?'. If it can fit into the SNA network, then the control centre allows the equipment to plug into the network. Any device that is non-SNA-compatible is made compatible through protocol conversion. The integrated telecommunications network supports voice, data, and image transmission from any part of the network to another part of the network.

The central network management centre is located at Phoenix, AZ. The company is building a centralized network management system that would troubleshoot the network, control the network, and provide comprehensive management information. These reports track user costs for services, as well as use of network nodes, intermachine trunks, access lines and traffic around the world. These reports are used as strategic planning tools. The system can tell operators exactly what the problem is and where it is located. The system can manage every piece of the equipment over the network through a single Netview console. In such an architecture, the company expects the users to use flexible systems but to work within the constraints imposed by a centralized control centre.

Tradeoffs among alternative information architectures

Now that we have classified the IS architectures that support the organizational structures, one of the most important questions is the relative advantage of each architecture. The cost variables used by Gurbaxani and Whang,[21] Malone[22] and Malone and Rockart[23] are synthesized and used to compare the above architectures. There are three costs variables that we consider: production, coordination, and vulnerability. They are examined in the context of information technology resource consumption. Basic definitions of the cost variables follow.

Production costs are proportional to the amount of processing capacity and databases required in the organization and how economically they are used in processing the inputs and producing the outputs.

Coordination costs measure the costs involved in communicating across the various IT resources in the organization and in integrating the information.

Vulnerability costs are the unavoidable costs of a changed IT situation that are incurred before the organization can adapt to the new IT architecture. Typically, these are costs incurred due to IT resource failure/degradation.

Table 1 shows an assessment of these three costs for the IPTS element of the information architecture, while Table 2 shows the same assessment for the IMCS element. Note that the relative cost comparisons (low, medium and high) are made column-wise, and not row-wise.

Table 1. *Impact of IPTS on costs*

IPTS option	Production costs	Coordination costs	Vulnerability costs
Centralized	Low	Medium	High
Decentralized	High	Low	Medium
Integrated	Medium	High	Low

Table 2. *Impact of IMCS on costs*

IMCS option	Production costs	Coordination costs	Vulnerability costs
Centralized	Low	Medium	High
Decentralized	High	Low	Medium
Integrated	Low	High	Low

Looking first at the IPTS element in Table 1 and the production cost column, note that the production costs are lowest where DBMS and processing are centralized since economy of scales can be achieved. Decentralized processing and DBMS imply duplication and redundancy leading to higher production costs. With integrated IPTS, some sharing can occur leading to medium production costs. Examining the coordination column, there is very little or no communication in decentralized systems, while there is extensive communication in integrated systems. In centralized systems, there is limited communication from the I/O devices to the central site. Finally, looking at the vulnerability column, the central site is the most vulnerable due to the exclusive reliance on the centralized resources for all types of processing. The integrated option is the most reliable, as processing can be redirected to another node in case of node failure. In the decentralized mode, the vulnerability costs are localized as only the failed node is affected while all other nodes continue to operate as usual.

The effect of IMCS on the three costs is similar, as shown in Table 2. The only minor difference is in the production cost, where we hypothesize that both centralized and integrated control would be able to lower production costs by a suitable reassignment of the workload to the IT resources.

As before, the feasible IT architectures are generated by combining the two elements. The cost tradeoffs for each architecture is shown in Figure 3. These tradeoffs are generated using the individual element tradeoffs from Tables 1 and 2. For easier reading, we have converted the ranks to an ordinal rank with a range of 1 to 5, where 1 is low cost and 5 is high cost. Clearly, each architecture has advantages and disadvantages associated with it, which is what makes the choice of an architecture a critical and arduous task.

The choice of an architecture is not universal, and depends on the absolute magnitude and importance of each type of cost to the organization. For example, a computationally and data intensive firm (e.g., banks, insurance companies, credit card companies) would have high production needs and would select an architecture which reduces the production costs. On the other hand, firms that are more vulnerable due to lack of instant information (e.g., airlines, defence) will select architectures which provide protection against IT resource failure. The case of the all-decentralized architecture is special, and will be used where there is relative autonomy among the various units of the organization (e.g., conglomerates); thus coordination is not needed and is minimized by using this option.

IPTS \ IMCS	Centralized	Decentralized	Integrated
Centralized	P = 1 C = 3 V = 5	Inappropriate	P = 1 C = 4 V = 3
Decentralized	Infeasible	P = 5 C = 1 V = 3	Infeasible
Integrated	P = 2 C = 4 V = 3	Inappropriate	P = 2 C = 5 V = 1

Figure 3. Information architecture tradeoffs (Key: P, production costs; C, coordination costs; V, vulnerability costs. Ordinal cost scale: 1 = low cost; 5 = high cost)

Another observation needs to be made while examining the tradeoffs. The choice of an architecture is not a static, one-time decision, but can be an ongoing dynamic determination. Architectural changes will be made as the strategic and business priorities of the company changes. One scenario for architectural evolution (not the only scenario) is the following: a company starts out with a centralized architecture, but the architecture gradually evolves into a decentralized form due to one or more of the following reasons: uncontrolled IT growth, business growth possibly by mergers and acquisitions, political reasons/empire building, and legitimate needs of different constituencies. If this new architecture becomes unwieldly, hard to manage, and unresponsive to business needs, then there are pressures to control by consolidation (move towards centralization), or requirements to coordinate and link the various pieces (move towards integration). One can easily find examples in the MIS literature[24] where companies have gone from one form of architecture to another in no universally uniform and consistent manner, and yet the selected architecture has been a good choice in each specific situation. The point is that each architectural alternative is suitable contingent on the unique business conditions at the time.

Another point to be made is that if a firm wishes to move towards total integration, our model provides three paths: a rapid move toward complete and total integration, a move toward facilities (IPTS) integration followed by total integration, and a move toward IMCS integration followed by total integration. The last two paths allow a staged integration, thus containing the risks. Of course, the firm may decide to stay with partial integration, and does not necessarily have to move to total integration.

Conclusions and topics for future research

The five information architectures provide a means for a manager to evolve to a desired IT architecture. By defining the elements, configurations, architectures, and examples, a manager should be able to classify the networks in an organization into these architectures. By generalizing beyond computer-based information systems, the architectures could also be used to classify voice, image and video communications. Further, cost comparison among the alternatives makes the tradeoffs explicit.

This framework is an improvement over the current ones since it operationalizes the definitions and provides examples. Further research is being performed to illustrate the history of how organizations have evolved their information architectures. Researchers working in a specific organization for a long period may be able to show how the information architecture in their organization had evolved using these architectures. Future researchers may focus on some of the specific architectures. It is expected that most organizations use a dominant architecture, while other architectures may exist in some isolated parts of the organization. Empirical testing with real-life information architectures will improve our understanding of the dynamic and crucial architectural decision.

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