

A modular Network Architecture for Lower Cost, High Performance Telemetry Processing

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ABSTRACT

There is a continuing need in the aerospace industry for lower cost and more maintainable telemetry data processing systems that can deliver a high level of performance. While systems based on the Intel family of x86 processors and Microsoft operating systems have seen increasing use in lower performance and portable applications, UNIX/VME based systems have been necessary to achieve required performance in higher end, multi-stream applications.

Recent developments in the computer industry now promise lower cost alternative to these systems. With currently available technology, it is now possible to provide a powerful distributed processor architecture based entirely on commercial products. The system takes advantage of the latest of Intel Pentium processors, the PCI bus, 100BaseT Fast Ethernet, Microsoft Windows NT, ActiveX technology and NT servers. The architecture offers both current and future cost advantages for test facilities which must support a diverse set of requirements and which must maintain and support systems for many years.

KEYWORDS

Multi-Stream Telemetry, Network Telemetry, PCI, Windows NT, ActiveX

INTRODUCTION

The design of current multi-stream processing systems has been driven primarily by two factors - the need to maintain accurate time correlation between asynchronous data streams and the need to provide adequate processing power to decommutate and process the multiplexed data from each stream.

Time correlation has been performed by merging the asynchronous data from different streams on a bus and interleaving the merged data with time tags of the appropriate resolution. Because standard computer busses have had insufficient usable bandwidth for

this merged data stream, current systems depend on some form of proprietary bus to carry the real time data. Data words placed on the proprietary bus are appended with an identity tag which is used by processors to access bus data and to direct processing and routing of the data.

Processing of the data has been performed by either standard or custom processor boards with some auxiliary hardware interface to the proprietary bus. The cost of processors with enough power to perform the necessary real time processing has also been a factor in driving this architecture. The high cost dictated that each processor should be able to access any data from any stream so that the processor resources could be used flexibly to meet differing test scenarios.

The technology that has become commercially available during 1996/97 has made it economically desirable to take a different approach to the architecture of multi-stream telemetry processing systems. The low cost and high performance of the latest generations of processors, operating systems and LAN products has made it practical to design a multi-stream, high performance telemetry processing system using a distributed, networked architecture.

The low cost of the powerful Pentium family of Intel processors allows single board computers to be dedicated to the processing of data from a single stream. Single board computers with the appropriate processing power can be selected to meet the needs of the system. By time tagging measurements from each data stream using a common time base, the necessity of merging all data streams on a common bus for time correlation purposes is eliminated.

Use of current networking technology and measurement time tagging allows all data to be routed to a central server and correlated for processing and archiving. The low cost of 100BaseT Network Interface Cards (NIC) and the built-in operating system support for TCP/IP makes dedicated 100 Mbps Ethernet an appealing method of moving data from distributed stream processors to the central server.

The features of Microsoft's Windows NT makes it an excellent choice as an operating system for the networked system. It provides the security features necessary in environments with large numbers of users and was developed to be used in networked environments. The Windows NT operating system has been designed to support symmetric multi-processing (SMP) applications and to operate with up to 32 parallel processors. This flexibility provides a wide range of processing power which can be scaled to meet the needs of specific applications.

Although any processor running the Windows NT operating system can be used for the central server, servers based on the Intel Pentium Pro and running the Microsoft Windows NT operating system are an excellent choice. The Pentium Pro is the sixth generation x86 microprocessor introduced by Intel and has been optimized to execute 32 bit code. The Pentium Pro was designed for workstation and server class computing, and it contains glueless logic supporting up to four-way SMP. Bench marks show that a dual-processor Pentium Pro system running Windows NT will scale performance by 1.7 for processor intensive operations, and a quad processor Pentium Pro system will scale performance by 3.3.

HARDWARE ARCHITECTURE

Figure 1 shows the configuration of a modular network architecture system. It consists of Stream Processors either installed on the server PCI bus or connected to the server over dedicated point-to-point 100BaseT network connections. If output of EU Converted DAC data is required a DAC Processor may also be added. The system control and data display functions are performed over a second network which consists of one or more clients.

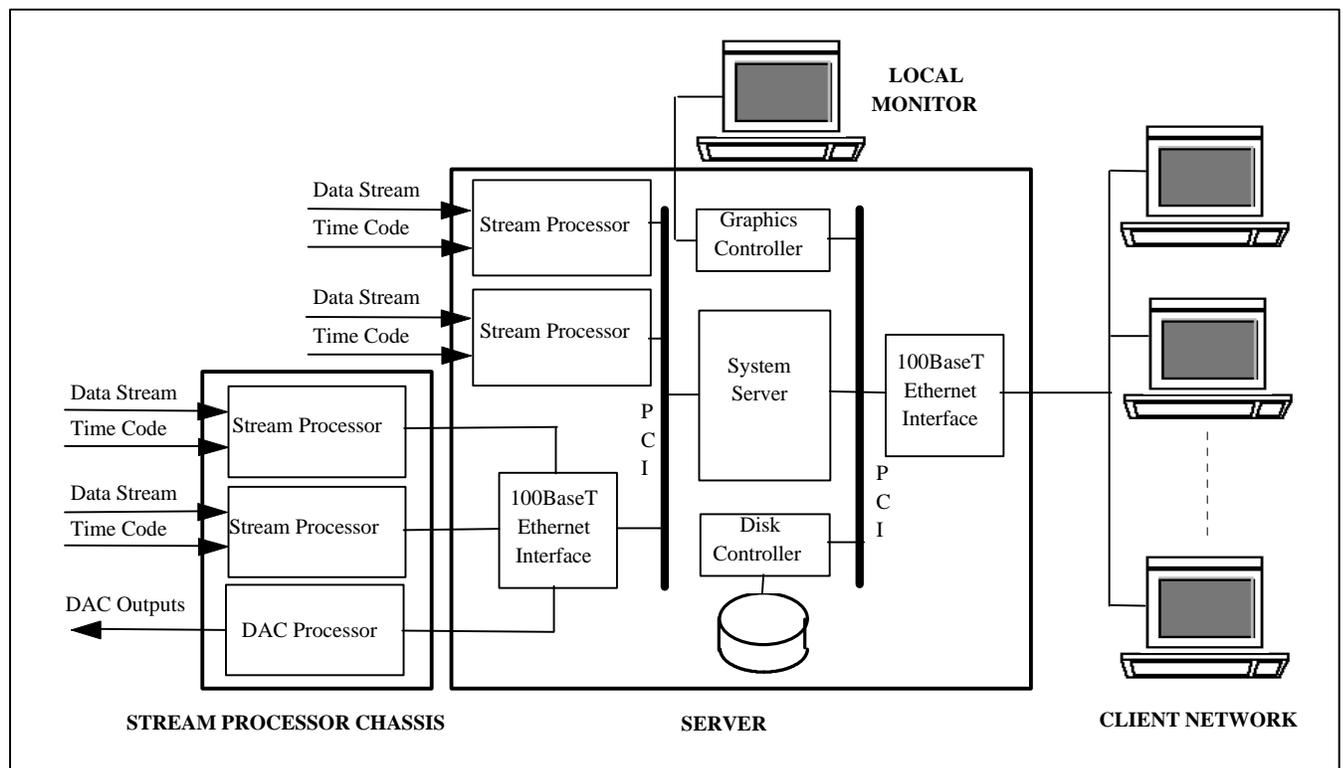


Figure 1 - Configuration of the Modular Network Architecture System

Stream Processors

There are two categories of stream processors which may be utilized depending on the system configuration - internal and external. An external Stream Processor consists of a data interface on an ISA or PCI module, a Single Board Computer (SBC) and a 100BaseT NIC. A separate SBC is used for each external Stream Processor except in the case of processing Chapter 8 1553 data which is spread across multiple tape tracks. The ISA and/or PCI modules are mounted in a 5 slot passive backplane segment. Four of these backplane segments can be mounted in a 19" chassis providing up to four input streams in a single chassis. An internal Stream Processor consists of a data interface card installed in the server and utilizes the server processor.

For PCM, the data interface can be an SBS9900 PCI card capable of decommutating data up to 24 Mbps. This module is a single board telemetry system with a 24 Mbps PCM Decommutator, IRIG A,B or G Time Code Reader/Generator and 16 Mbps Bit Synchronizer and occupies a single PCI slot width. Figure 2 is a block diagram showing two examples of external Stream Processors.

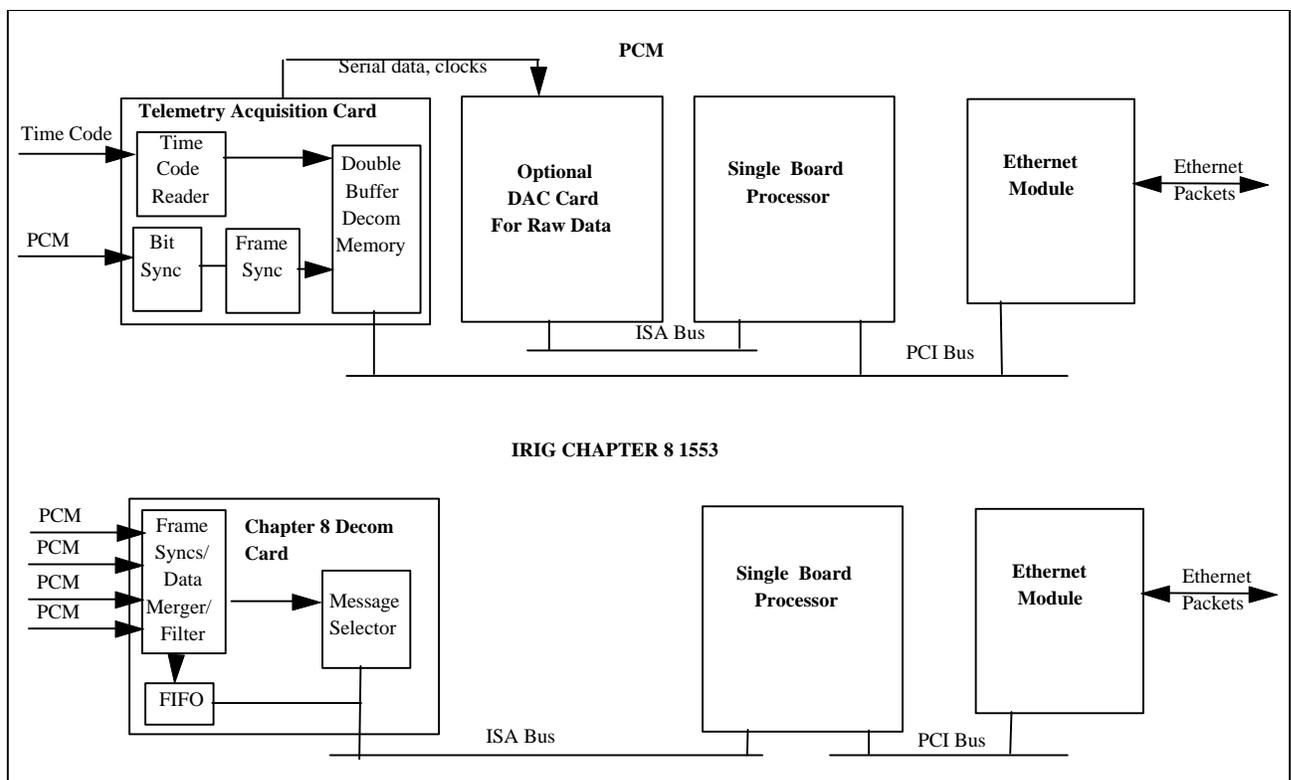


Figure 2 - External Stream Processor Examples

The SBCs used in external Stream Processors conform to the PCI Industrial Computer Manufacturers Group (PICMG) standard. Computer boards complying with this standard have both an ISA bus interface and a PCI bus interface. The entire Pentium family of processors up to and including dual Pentium Pro 200 MHz processors are available in this

form factor from multiple sources. The 5 slot backplane segments provide a PICMG processor slot and a combination of four PCI or ISA slots depending on the requirement. When ISA based telemetry or other interface modules are used, the dual bus structure allows the processor to utilize the full 16 Mbytes per second bandwidth of the ISA bus to receive data from the module. When the stream interface is a PCI module, the processor, stream interface and 100BaseT NIC all share the 132 Mbytes per second PCI bus.

Stream Processor/Server Network

Each external Stream Processor is connected to the server through a dedicated 100BaseT Ethernet connection. To conserve PCI slot space on the server, quad-port 100BaseT PCI NIC's are used. These are available from a number of suppliers and are capable of supporting full duplex communications on all four ports simultaneously for an aggregate throughput of 800 Mbps. Tests conducted and reported in Reference 1 on a number of 100baseT modules demonstrated actual throughputs of 80 to 90 Megabits per second.

The system software is designed so that the majority of data transmissions utilize the maximum Ethernet packet length of 1518 bytes to minimize the overhead incurred by TCP/IP. The testing reported in Reference 1 showed significant differences in the CPU load imposed by different NIC devices with variations of as much as 4 to 1 between products from different suppliers. The module with the lowest overhead imposed a server CPU loading equivalent to about 6% on a single Pentium Pro 200 processor when transferring at its maximum bandwidth.

Server

The Server used can be sized to fit the system and readily upgraded. The basic server utilized is an off-the-shelf server package which includes 1 to 4 quad Pentium Pro processors and dual peer PCI busses. For high powered computing environments, larger servers using 8 or 16 processors are available which are constructed from multiple quad processors using high speed data pathways to interconnect them. Because of the distributed component design employed in the system software, additional computing power can also be obtained by adding a separate additional server to the networked system.

Client Network

The user interface for system control, database maintenance and data display is a web browser. The client network can consist of an assortment of PC's, workstations or network computers. The choice of clients is based largely on how the user wishes to interact with the system. Database updates and real-time data display can be performed with limited desktop power required. However, for intensive analysis requirements the user may need to download large data files and use more powerful workstations for analysis.

Data Archival Hardware

The archiving hardware required is driven by the bandwidth of the system. A wide range of choices with trade-offs between cost and performance are available. As an example of the high end performance available, Intergraph offers a RAID system with their servers which utilizes three Fast/Wide SCSI II controllers and provides sustainable transfer rates of 29 Megabytes per second. This particular system utilizes hot-swappable 4.0 Gbyte drives and can be expanded to 300 Gbytes of storage.

DATA PROCESSING CONCEPTS

There are some concepts that are key to successfully processing telemetry data using this architecture.

Time Correlation

Time correlation is maintained among the asynchronous stream processors by supplying a common IRIG time base to each and defining a common time interval over which each processor will buffer data before initiating transfer to the server. Each processor aligns the start and stop time of each buffer period on common time boundaries. In cases where significant differences in data rates exist, certain stream processors can transfer data at submultiples of this common time interval. All data samples within the data buffer are tagged with a minor time.

Mapped Data Blocks

As the data values are processed, the time tagged data samples are sorted by measurement into arrays and mapped into predefined locations in the stream processor memory buffer. At the end of the buffer time interval, transfer of the mapped time block for the stream is initiated and it is transferred via TCP/IP to the server using maximum length Ethernet packets. As the server receives the time blocks from each link they are mapped by link number into a buffer area which results in a mapped block of time tagged data samples containing all data values from the time slice defined by the start and stop time boundaries of the buffer period.

Alarms

Latency in transferring of alarm data from the stream processor is eliminated by transferring alarm packets to the server as they occur. For measurements that are limit checked or monitored for a change of status, values determined to be in alarm are time and identity tagged and transfer immediately to the server using a minimum length Ethernet packet.

SOFTWARE ARCHITECTURE

The system software is designed for intranet operation in a distributed computing environment and utilizes Microsoft ActiveX technology. Telemetry data processes are encapsulated in ActiveX Components communicating with each other using Distributed Component Object Model (DCOM) protocol. The use of DCOM facilitates the distribution of objects over networks and allows the ActiveX Components to execute either on a client computer or a server computer transparent to the calling application.

Because the ActiveX Components are relocatable, they can be distributed over the system hardware environment as needed. This approach allows a common set of system software to be scaled over a wide range of system requirements. Small single stream, low performance systems can execute all necessary components on a single processor. For large, multistream, high performance systems the stream processing components can be distributed among the SBCs in the external Stream Processors. These SBCs each function as application servers dedicated to a single input stream. Multiple users are added by distributing display and control components to the networked client computers. If the system requires further expansion, additional clients and servers can be added to the system and the ActiveX components distributed accordingly.

The user interface utilizes the Internet Explorer web browser. All functions for telemetry format description, data conversions, system operation and data display are readily accessed from web pages which make extensive use of embedded ActiveX Controls. An ActiveX Control is a client-side component which when activated by the user can directly access database files, archive files and real time data tables which reside on application servers. Figure 3 illustrates the major system software components.

Web Browser

The web browser currently used is Internet Explorer. The browser interprets HTML pages and displays the resulting information. It includes support for HTML, scripting, Java Applets, ActiveX components and ActiveX controls.

Web Server

Microsoft Internet Information Server (IIS) 3.0 web application server provides the integrated services required to manage the system execution and data flow. It provides a server-side component and scripting model and required services for component application management, database access, transactions and processing. The web server can return data to the clients as straight HTML or alternately establish a direct connection back to the component running in the client using DCOM protocol. IIS is distributed as part of Windows NT and is tightly integrated with that operating system.

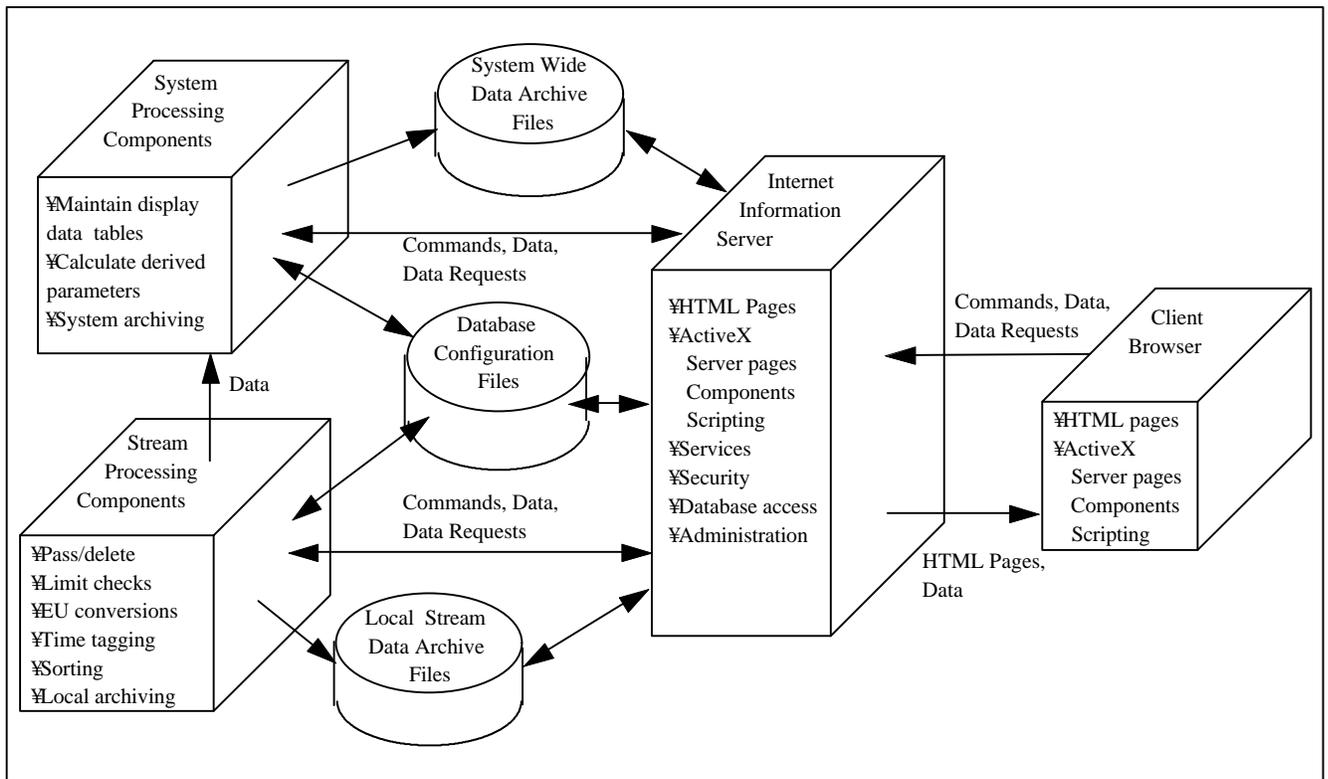


Figure 3 - Major Software Functions

Stream Processing Components

Components of the stream processing software reads the data and time from the stream interface and performs real time sample by sample processing. Pass and delete of specific measurement, limit checking, data alignment and concatenation are performed in this software partition. Data can be output from the processor in integer or floating point formats. If real time EU conversions on all data samples is required it is performed here. For PCM data, time tagging is performed using the microsecond resolution time which is merged each minor frame in the Terametrix hardware. For supercommutated measurements, interpolated time is used to tag successive values in the same minor frame. Following all data conversions, the data values are sorted into the mapped buffers.

System Processing Components

This set of components receives the data blocks from the stream processors and properly time aligns the blocks from all links. A current value table of all measurements as received from the stream processors is maintained as well as a table of arrays of data sample from designated measurements. User processes for creating derived calculations can be written in C++ or Terametrix Telemetry Data Language (TDL) script and are executed at this level. Similarly custom engineering units conversions can be user written and installed and processed at the stream level.

Archive/Recall

At the system wide level, the archive/recall process builds the data buffers and archive the data to disk. The data from all input streams is initially buffered in the server as mapped blocks containing all measurements during a unit of time. These blocks are archived to disk and are the basic data element used for searching for and retrieving data. The archive/recall process provides the user with the ability to create search criteria to isolate specific data sets.

The recall process utilizes this data mapping to index to specific times and specific measurements in the file for retrieval of measurement time histories for analysis. This technique avoids the problem that exists in many current systems in which the archive file produced consists of data from all streams merged in a sequential file and identifiable only by tag. Retrieval of a time history for a specific measurements in those files requires performing a sequential search on all data in the file for time tags and identity tags.

Due to the distributed architecture of the software systems with independent data streams not requiring time correlation could perform archiving at the individual stream level without affecting the accessibility of the data.

Data Display

Data display for both real time and playback data is implemented using a package of web enabled components from DataViews which provide the capability to display dynamic graphics over Internet/Intranets. The dynamic graphic displays are embedded into HTML documents and connected to the real time current data tables, or for playback, the archived data files to create the data displays. A library of standard display objects can be utilized or custom display objects can be created using the DataViews tools.

Configuration Files

System configuration files are maintained in a relational data base. Data is accessed by the clients and servers via the Internet Information Server. The file transfer standard for import/export from the database is in accordance with an extended version of the IRIG Telemetry Attributes Transfer Standard (TMATS). These files provide the compatibility link between and current user databases. The files can be built and updated from the system user interface or can be maintained from standard text editors or spread sheets.

INITIAL IMPLEMENTATION

An initial implementation of this system concept was successfully built and shipped in April 1997. The system input consisted of ten 2 Mbps PCM streams and is designed to be easily expanded to accommodate 12 streams. Physically, the system is comprised of ten Stream Processors and a Pentium 200 MHz processor that functioned as the system server which are housed in three 8 3/4 inch rack mount chassis. Each Stream Processor consists

of a TAC-1 Telemetry Acquisition Card, a 12 channel Digital to Analog converter card, 486DX4-120MHz processor and an Ethernet interface.

The software technology currently used did not exist when the initial project began and therefore the software implementation differed substantially. The initial implementation ran Windows NT on the server and Windows 95 on the stream processors. National Instruments LabWindows was utilized for the user interface as a result of customer requirements. The server console provided real time data display via LabWindows VI's. The user was provided with the capabilities to create his own displays, create and run derived calculations in the server and to create and run his own algorithm processes in the stream processors. The system output all the assembled data from all links via a network interface to another computer.

Experience with this system proved the viability of the distributed architecture in a multi-stream environment and set the stage for the current system design using the distributed object software architecture.

CONCLUSIONS

The modular network telemetry processing system architecture described offers many advantages to the user community both now and in the future. Among these are:

- No proprietary processors - Standard, single board computers and servers perform all processing.
- No proprietary bus - All data moves over well developed industry standard busses and networks
- Multi-Vendor - Uses commercial data I/O interfaces and processors with multiple vendor sources
- Scalable - Cost is proportional to the number of streams and processing power.
- Upgradable - Old processors are easily replaced as new processors evolve
- Component object software - Components can be easily added or replaced
- Leveraged future - Follows the evolution of Intel and Microsoft products.

ACKNOWLEDGMENTS

Pentium is a trademark of Intel Corporation

Windows NT is a trademark of Microsoft Corporation

REFERENCES

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