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On some aspects of packet switching technique relevant to meteorologial application

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सार – संकुलन स्विचन (पैकेट स्विचिंग), संगणक (कम्प्यूटर) आधारित संचार की एक नई तकनीक है जो कि आंकड़ा संचार क्षेत्र में प्रभावी विधा होती प्रतीत होती है। वर्तमान सुविधाओं की सीमाओं की चर्चा करने के बाद लेख में संकुलन के गुणों, विभिन्न सेवाओं के प्रदान करने और सहयोगी संजालों पर विशेष जोर देते हुए इस नई तकनीक के खास-खास गुणों की समीक्षा की गई है। टरिफ विधियां और विभिन्न निस्पत्तिमानदंड, जोकि ऐसे संजाल के प्रतिरुपण में सहायता करते हैं, का विवेचन किया गया है। असमांग कम्प्यूटरों के आंतरिक कार्य के लिये समर्थ बनाने वाली खुली प्रणाली की अंत: संबंध वास्तुकला के लिये अन्तर्राष्ट्रीय मानकीकरण संगठन के उभरते हुए मानकों का भी वर्णन किया गया है। लेख के अंत में भारत में मौसम विज्ञान की सेवाओं के लिये संकुलन स्विचन आंकड़ा संजाल का संक्षिप्त में प्रस्ताव दिया गया है।

ABSTRACT. Packet switching is a new computer-based communication technique that promises to be the dominant mode in the data communication field. After discussing the limitations of the current facilities, the paper reviews the salient features of this new technique with special emphasis on the characteristics of packets, different services offered and the associated networks. Tariff methods and different performance criteria that help in modelling such a network have been discussed. The emerging standards of ISO for Open Systems Inter-connection Architecture enabling interworking of heterogeneous computers are touched upon. The paper ends with a brief proposal for a packet switched data network for the Meteorological Service in India.

1. Introduction

Telegraphy and, later, telex and leased circuits have been the traditional communication modes employed by the meteorological services around the world for exchange of weather observations and processed information. Subsequently, the Public Switched Telephone Network (PSTN) made it easier to have a multiple access, faster, more reliable and efficient data communication network over widely dispersed geographical areas. In India, the PSTN is still not commercially available for general data communication use. With the increased volume of data traffic and the need for faster, more reliable and flexible data communication links, the limitations of the existing networks became obvious in recent years over most parts of the world. A redically new computer-based technique, called packet switching, has very recently been introduced in the data communication field, which overcomes many of these limitations and has the potentiality for ushering in a radical change in handling data traffic. Rapid development in micro-electronics (LSI and VLSI) is primarily responsible for its wider practical realisation and economic viability in recent years. It must be said, however, that the basic principle of packet switching, *viz*., dynamic allocation of communication facilities was known for a long time in some form or other *e.g.,* mail, telegraph etc. What was needed was re-evaluation of the technique and its successful application to a new task, *viz.*, electronic data transfer. In fact, depending upon the nature of data traffic handled, packet switching using dynamic allocation is 3-100 times more efficient than the pre-allocation technique in utilising available channel resources (Roberts 1978).

To Paul Baran of Rand Corporation, USA goes the credit of first publishing the description of a fully distributed communication technique now known as packet switching (Baran 1964). The idea was further developed by Davies of the UK National Physical Laborartory (NPL) who first used the word *"packet"* (Davies *et al.* 1967) and Roberts of the Advanced Research Project Agency (ARPA) in the USA (Roberts 1978). By the early 1970s, both the NPL and ARPA started operating packet switching networks. The ARPANET was particularly the focus of considerable early research on the new technique leading to a solid theoretical foundation for different packet networks that were to follow (Trivery 1980). By the late 1970s, quite a few private and public data networks started functioning on packet switching technique. Thus ARPANET and the NPL experiences gave rise directly to Telenet in the USA and Datapac in Canada. Other examples are the EPSS (Experimental Packet Switched Service) in the UK, European Informatics Network (EIN) sponsored by EEC, EURONET of the European Community, TRANSPAC and CYCLADE networks of Europe (Bleazard 1979). Packet Satellite and Packet Radio Networks also have been established recently (Jacobs *et al.* 1978 and Kehn *et al.* 1978).

There are certain features of this new technique which make its use in the meteorological environment an attractive proposition. For example, it enables different subscribers to share the storage and processing capacities of the computers in the network and also the capacity of the communication links on dynamic allocation basis. Naturally, the World Meteorological Organisation (WMO) became interested in the packet switching system and its possible use in a future Integrated World Weather Watch Programme. The technical, financial and operational aspects of introducing this data communication mode in the Global Telecommunication System are being intensively discussed in the various WMO forums and working groups (WMO 1979, 1980). Unfortunately, much of the information relating to packet switched networks and the associated Open Systems Interconnection Architecture is still confined to a few specialised journals and to the working papers of various standards Committees and working groups of bodies like CCITT, ISO etc active in this area. The purpose of the present paper is two-fold. First, a review is made to bring out the salient features of packet switched data networks and the associated open systems architecture concept so as to bridge the gap between the highly specialised technical groups and the practising meteorologists and engineers. Secondly, a proposal is outlined for a possible packet switched network for the meteorological environment in India.

2. Current facilities and their limitations

For high density and evenly distributed internal traffic between two points, the leased circuit is probably the most popular data communication mode. For multiple access to a larger number of points with the wide geographical separation, the circuit switching technique is preferred. Telex and PSTN fall in this category. Leased circuits have high development costs, higher reliability, high acquisition lead time, and provide permanent connection beween two points. PSTN, on the other hand, needs as much as about 20 seconds to connect a call, which is prohibitive in many applications. In both the systems however, it is the subscriber's responsibility to arrange for interfacing dissimilar equipment. In another data transmission technique, *viz.*, message switching systems, the data is stored and automatically routed to the desired channels by means of a switching computer. Unlike circuit switching, here no physical path is established between the sending and receiving legs. The data is stored and then automatically sent in bursts or continuous streams, simultaneously to a large number of points at appropriate speeds, which is an improvement over PSTN or leased circuits. However, this is not enough. For example, in all the current facilities tariff is not directly related to the quantum of data handled and one has to pay even if there is (disguised) under-utilisation of the circuits. It is not possible to exchange data between dissimilar network. Neither is there any provision for automatic alternative routing when some channels fail or are congested. Further, a small user incapable of investing heavily in computer facilities or lines is often denied access to the quality of service and facilities enjoyed by larger users. Since in the current data transmission techniques the particular customer holds on to the channel exclusively for his own use once the call connection takes place and even if no information is actually transmitted, there is often considerable under-utilisation of the facilities. Though the message switching system partly solves some of these problems, the need for a new technique involving dynamic allocation of facilities becomes apparent. The packet switching technique which is really an extension of message switching technique working on store and forward mode overcomes many of the limitations mentioned earlier while simultaneously retaining many of the desirable features of the existing facilities.

3. Packet characteristics

As indicated above, packet switching has evolved out of the message switching system. It utilises a network of communication computers for routing a specially formatted packet of data from an originating station to a destination station. The data stream in any form, coming from

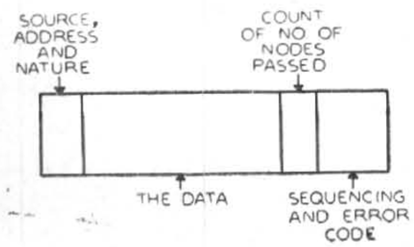

Fig. 1. Structure of a data packet

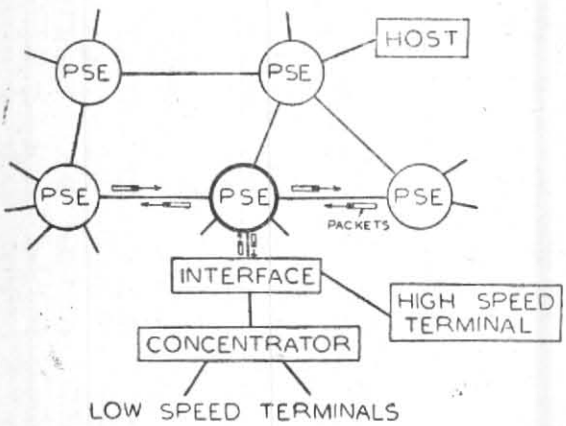

Fig. 2. Schemetic diagram of a packet switched data network

a subscriber is segmented into small data blocks and formats. To each of these blocks are added address, supervision, control and error fields to make them rigidly defined data segments (packets) (Fig. 1). The packet lengths may vary between specified maximum and minimum limits. The structure itself may vary from network to network. In Davies' System a packet may contain one to eight segments of 16 bytes of eight bits each (*Davies et al.* 1973). The maximum length is thus 128 bytes, which is adequate to accommodate a majority of the messages. Longer messages will form many such packets each of which will carry source and destination addresses, and will thus travel as physically and logically independent entities over dynamically allocated links and other network facilities. This is the Datagram mode of operation.

4. Packet switched network

The subscriber's data, once these are put into a data envelope or packet, rushes through high speed links between the Packet Switching Exchanges (PSE) which are node computers. The overall network is shown schematically in Fig. 2. For better channel utilisation a few low speed subscribers are normally bunched together by a concentrator or terminal duster controller employing TDM technique and then fed into an interfacing computer which formats the data into packets. The high speed terminal, however, can perhaps be connected directly to the interfacing computer. The PSE consists of one or two minicomputers. In some cases, *e.g.,* in the Interface Message Processor (IMP) of ARPANET, the interface computer and the PSE are combined into one (Green *et al.* 1975). A trunk line speed of 9,600 bps or more is common. A PSE, after getting the packet, sends it immediately to the next PSE nearest to the destination as indicated in the header of the packet. The packet thus travels from one PSE to the next till it reaches the destination. If for any reason the preferred node is busy, or malfunctioning, or the link is busy, there is provision for automatic rerouting of the packet through the link which is free to accept it. The packet thus passes very quickly through the network till it reaches the destination. The channel is dynamically allocated by the PSE to various packets, not necessarily from one source, and thus queue formation is avoided besides ensuring a high degree of channel utilisation. It also enables the data to reach the destination even if part of the network is malfunctioning or destroyed by, for example, enemy action during the war. The following characteristics are important :

(*i*) Packets formed out of a simple message will reach the destination at different times depending upon the route followed and hence the end of a message may reach earlier than the beginning. Though the interface computer of the destination local area sequences the packets properly and thus ensures data transparency, time transparency is lost. Thus the datagram mode is not very suitable for voice transmission and certain real time process control application. However, an attempt has been made to use packet switched data networks for handling of digitized voice communication also (Gitman 1978).

(*ii*) Formatting of the message into packets is the responsibility of the network and hence the subscriber need not invest heavily on his terminal equipment. For asynehronous start-stop mode of operation, Packet Assembly and Disassembly (PAD) is normally done according to the X3, X28 and X29 protocols defined by CCITT by the PAD unit. As its name indicates, the PAD assembles the characters into packets destined for a packet mode DTE and similarly disassembles the in-coming packets for sending them to a start stop mode DTE.

(*iii*) In order that the data is not lost, the links have to work in full duplex mode so that the recipient node, after checking the error code in a packet, can confirm its proper reception. The sending node can then erase the packet already received by the next node or, if not, repeat it. For operating virtual call, full duplex working is necessary in order to exchange call indication, call acceptance etc between two nodes.

(*iv*) It is necessary to control the number of node transite by a particular packet in datagram node since otherwise it may circulate in the network indefinitely.

(*v*) With a standard structure of the packets, some parts of the processing in the switching computers (*e.g.*, link access procedure of CCITT X-25 protocol) can be hardware based and standard software can be used for many parts.

(*vi*) Because of the short queues, storage requirement at the PSE is limited and hence the data queues can be held in the fast access memory making the operations quite fast.

5. Services offered

The datagram mode of packet switching, in which self-contained entities of data carrying enough control information zip through the network, independent of each other, has been explained above. Though high reliability is achived in this mode, the costs associated with more complex routing and message processing required besides the overhead in putting enough control information in each packet to make it self-contained, often discourage its use. An alternative is the Virtual Circuit mode of operation. This term is applied to the period of time between the call set-up and call clear when the two users are effectively interconnected for transfer of data (CCITT defn. 53, 54). Here the actual data transfer phase is preceded by the exchange of call request and call acceptance packets. Similarly, the call is terminated by exchange of call clear request and its confirmation. It is possible to establish Permanent Virtual Circuit between two terminals when the network transmits all the packets received from one terminal to a second designated terminal as though a dedicated leased circuit connects the two terminals (CCITT defn. 53, 54). There is also Fast Select Call Facility where the data packets follow the call request packet without waiting for a call acceptance packet and thus the virtual circuit is established very quickly. In some types of virtual circuit operation, automatic reconnect capability is used to insure against connection failures.

In all the above modes of work the data terminal can carry on several calls simultaneously over a single physical link by dynamically allocating different network facilities.

6. Communication efficiency of PSN

The main traffic implications of the Packet Switched Network (PSN) are:

(*a*) Control and other added information work as overheads and the processing requirement at the nodal computers is increased; and

(*b*) Data holding times are reduced.

Both these factors are important determinants in the overall performance of the network. It is of great consequence to determine that packet size which is an optimal compromise between the added overheads and the probability of retransmission of a packet due to errors since such multiple transmission results in prolonged occupation of network facilities (Chu 1974). A study of the relative efficiency of different protocols under a given set of performance specifications is also necessary before choosing the appropriate protocol (Majithia *et al.* 1974, Fayolle *et al.* 1978). Studies relating traffic and protocol parameters considering the efficiency factors introduced by the protocols are important inputs to the network design since such studies give useful information for the selection of the right protocol flow control parameters (Miguez *et al.* 1980).

An important figure of merit that greatly influences the network design and routing algorithm is the delay a packet suffers in a network. If the model processing time is k and the channel propagation time of the ith channel is P_i, application of queue theory gives the average message delay T in the network as (Frank *et al.* 1972),

$$T = k + \sum_{i=1}^{M} \frac{\lambda_i}{\gamma}\left[\frac{\lambda_i\, \alpha'/C_i}{C_i/\alpha' - \lambda_i} + \frac{1}{C_i/\alpha} + P_i + k\right]$$

Where,

λ_i = Packet arrival rate at the ith link with the packets arriving independent of each other,

γ = total traffic entering into the system,

α' = average length of all packets (bit/packet),

α = average length of data packet,

C_i = transmission speed of ith link.

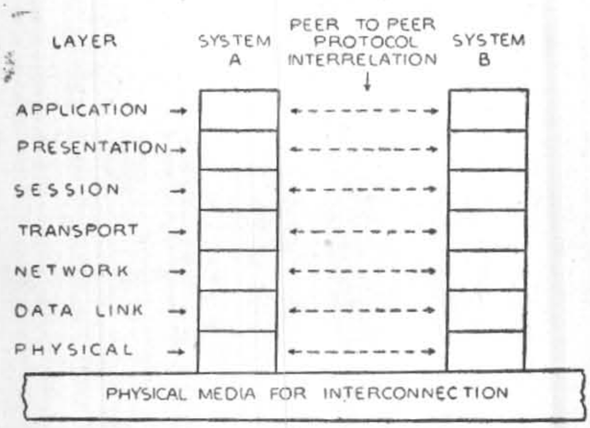

Fig. 3. Seven layer Reference Model and peer to peer protocol inter-relation of the ISO Open System Architecture

The above expression is deived from the fact that the packets are transmitted over a collection of switching nodes and, therefore, the queueing model for a packet switched network is a multi-stage tandem queue (*e.g.*, Kobayashi *et al.* 1977).

7. Tariff method

Because the data route between two points is not fixed but depends upon the availability of link and node at a particular moment, the tariff structure is usage-related and is distance-independent. Except for certain minimum and fixed charges dependent upon the overheads and terminal facilities, the rest of the charges are related to the volume of data transmitted and the type of usage. This is thus significantly different from most other modes of data communication by the utilities. In the UK public packet-switched service, the tariff structure has three components, *viz.*, access charges, usage charges and facility charges besides the once-only connection charges (Bleazard 1979). The access charges depend upon the Dataline model used in a customer's packet mode terminal. In the usage related charges, virtual calls and Fast Select virtual Calls are timed for the duration of the calls while the permanent Virtual Circuits have fixed rentals. Chargeable facilities include Reversed Charge Acceptance, Redirection of calls etc. In majority of the cases, the overall charges compare very favourably with the traditional mode of data communications.

8. Open systems interconnection architecture

One problem that crops up frequently in computer neworking is the need for interconnecting heterogeneous computer systems from different manufacturers using different network architectures which cannot be interconnected even though these may be functionally equivalent. The International Standards Organisation (ISO) recognised the urgent and special need for evolving standard conventions in this area and set up in 1977 a new subcommittee (SC 16) for "Open Systems Interconnection". The term 'Open' was chosen to emphasise the fact that by conforming to these international standards, any computer or terminal system connected to a data communication network will be able to communicate meaningfully with any other system in that network, *i.e.,* all systems will be open to all other systems. It may be mentioned, however, that the ISO architecture defines only the external behaviour of Open Systems while the internal functioning and behaviour of individual Open Systems are outside the scope of the ISO standards since these are not visible from other systems with which these are interconnected (Zimmermann 1980).

9. Layered architecture

The model developed by the ISO subcommittee and called the Reference Model of Open Systems Inter-connection is a seven-layered structure that enables modularisation of the task of data communication software design (ISO 1978 and 1979). The model is illustrated in Fig. 3 where successive layers are represented in a vertical sequence with the physical media for Open Systems Interconnection at the bottom.

Each layer in the model adds value to the services provided by the set of layers below it so that the highest layer is offered the set of services needed to run the distributed system. The services provided by each layer are independently defined on the basis of a set of transmission-related functions. No particular layer needs to know how the services it requests from the lower layer are actually performed or how the services it offers to the higher layer are utilised there. Such structuring has several advantages. Its simplified design and debugging, enables separate groups of people to design separate parts thus allowing specialisation, ensures clear interfaces between the layers, etc. Thus it becomes possible to modify any layer without disturbing others so as to accommodate subsequent changes in technology or functional requirement.

Each layer in such a hierarchical system is made up of one or several entities. Entities in the same layer are known as peer entities. Layer protocol defines the rules of interaction between the peer entities. Each layer of a system communicates only with its peer layer in the communicating system according to the predefined protocol. Thus, the session layer in one system communicates only with the session layer of another system.

10. Identification and purpose of seven layers

In defining the seven layers as shown in Fig 3, ISO considered thirteen general principles and applied them to determine where and how many boundaries should be placed. Each layer is chosen to handle functions manifestly different from others keeping in view the need for a minimum number of layers with interfaces at points where past experience has demonstrated success. Each layer interfaces with its upper and lower layers only and has provision for sublayers that are created by sub-grouping the functions in cases where distinct communication services need it. A brief description of the different layers is given below :

(*a*) *The Application Layer* — This is the highest layer servicing the user directly. Other layers exist only to support this layer.

(*b*) *The Presentation Layer* — It provides the set of services which may be selected by the Application layer to interpret the meaning of the data exchanged. The presentation — service is location independent and is considered to be on top of the session layer which provides the service of linking a pair of presenation entities.

(*c*) *The Session Layer*— This layer provides services for binding two presentation entities into a relationship and unbinding them. It also provides session - dialogue - service, *viz.*, control of data exchange and deliberating and synchronising data co-operation.

(*d*) *The Transport Layer* — It provides service for the transparent transfer of data between session entities. The transport service is required to optimize the use of the available communication services to provide the performance required.

(*e*) *The Network Layer* — It provides the transport entities with independence from routing and switching considerations, including the case where a tandem subnetwork-connection is required.

(*f*) *The Data Link Layer* — The purpose of this layer is to provide functional and procedural means to establish, mantain and release one or more datalinks among network-entities. A popular protocol for this layer is the ISO High Level Data Link Control procedures (HDLC).

(*g*) *The Physical Layer* — It enables establishment, maintenance and release of physical connections (*e.g.*, data circuits) between link entities.

The bottom three layers of the ISO model are roughly analogous to CCITT X.25 recommendations. There are quite a few protocols successfully operating with reference to X.25. Their use within the framework of the ISO Open Systems Interconnection are yet to be fully developed. The protocols applicable for higher layers are similar. However, in view of the progress already made by ISO, full definition of standards and protocols are expected to be completed shortly. These, no doubt, will have a profound impact on the data communication systems in future.

11. Meteorological network in India

We now briefly consider a scheme for introducing packet switching technique in the meteorological environment in India because of its obvious merits. Such a network would enable different forecasting centres in the country to (*a*) acquire weather observatinal data according to individual needs, (*b*) disseminate the processed informations and (*c*) hopefully make the computers at Pune and New Delhi accessible to different forecasting centres.

The present meteorological telecommunication netwok in India is organised on a regional basis. The Regional Collection and Distribution Centres (RCC) located in Calcutta, Bombay, Madras, New Delhi and Nagpur collect observations from different points either directly by leased line, telex and telegram or by teleprinter (T/P) through State Collection Centres (SCC) located in state capitals. The RCCs feed the data thus collected to the message switching computer at RTH New Delhi, which in turn distributes the data to various points according to the needs. Normally 50 baud lines are used though multiple 50 baud lines connect some of the RCCs to RTH New Delhi. The National and International traffic is exchanged through RTH New Delhi. While data traffic from any RCC to New Delhi is rather low only being that generated by the region alone, the reverse traffic from RTH New Delhi is very heavy since it contains the national and international data necessary for preparing full weather charts and forecasts. Thus channel utilisation is unbalanced and often partial with no automatic rerouting capability in case of failure of any circuit.

A network that could serve the purpose of the Meteorological Service in India is shown schematically in Fig. 4. Here the Interface Computers and the Packet Switching Exchanges are combined into single nodel units. Such augmented PSEs are located in New Delhi, Calcutta, Bombay, Madras and Nagpur. These will be implementing X.25 protocols and will also normally work in asynchronous start stop mode (PAD facility) in Internaional Alphabet No. 2 and 5,

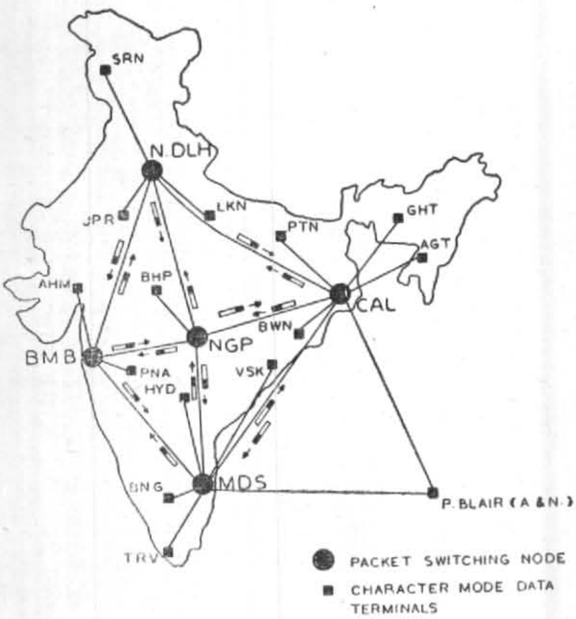

Fig. 4. Packet switched meteorological data network for India

They will thus be teletype compatible. Because of the need to avoid complicated maintenance problems, low traffic generation locally and for reasons of economy, smaller forecasting centres like Ahmedabad or Bangalore are provided with only teletype terminals. Their operating speeds can be raised upto about 300 bauds. These character mode Data Terminal Equipments will be connected to the network through PADs for two-way communication, the physical link being provided by the leased lines of the Posts and Telegraphs Department (P & T).

The whole network could work in Virtual Call mode with automatic reconnect facility. High density traffic over the trunk routes will be handled by Permanent Virtual Circuits. Data will flow from one PSE (representing one collecting region) to the other through any available free route. This will ensure negligible queue formation at each relay point, balanced traffic distribution over various circuit segments (as against the present heavy almost one-way traffic diverging from New Delhi) and hence better utilisation of the leased lines. Because of dynamic allocation technique, it will also be possible to have direct communication between an RCC like Bombay and an SCC like Ahmedabad over a single physical link without any need for going through RTH New Delhi as at present. Because of the automatic rerouting capability, temporary line failures will not seriously affect the data flow.

One problem in the Indian environment is the relatively common occurrence of line failures. Though automatic reconnect facility will remove much of the hardship in Virtual Circuit mode of operation, the utility of datagram mode of operation cannot be altogether ruled out in order to overcome this problem. We have chosen Virtual Circuit mode because of its low overhead and negligible occupation of network resources due to aborted transits. However, a detailed study of their relative advantages under Indian conditions with special reference to the optimisation of different network and traffic parameters and the problem of physical realisation is in progress and the results will be published in due course.

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