

# **GPS/GSM based train tracking system – utilizing mobile networks to support public transportation.**

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## **Abstract :**

The paper presents a solution implemented at Sri Lanka, to provide an intelligent train tracking and management system to improve the existing railway transport service. The solution is based on powerful combination of mobile computing, Global System for Mobile Communication (GSM), Global Positioning System (GPS), Geographical Information System (GIS) technologies and software. The in-built GPS module identifies the train location with a highest accuracy and transfers the information to the central system via GSM. The availability of this information allows the Train Controller to take accurate decisions as for the train location. Location data can be further processed to provide visual positioning using maps granting a wholesome view on train location. Positioning data along with train speed helps the administration to identify the possible safety issues and react to them effectively using the communication methods provided by the system. Additionally, the location information can be used to facilitate accurate scheduling with regard to train arrival and departure on each station.

## **Introduction**

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Rapid growth in the field of Information and Communication Technology (ICT) is a worldwide phenomenon experienced today. Emergence of wireless and mobile technologies plays a key role in the global ICT boost, unfolding a new era of communication technology. Global private sector was the first to explore the endless opportunities and potential of wireless technologies, by redesigning the business processes with the integration of latest wireless and mobile technologies to have the competitive advantage in the business world. Today, the ability to achieve organization's goals depends purely on the availability, accuracy and reliability of the information.

Governments worldwide have also recognized the high potential in the ICT sector and are using it as a core instrument to facilitate government processes and functions with the goal of uplifting the current standards of living of the society. Governments today are inspired by the concepts like eGovernment and mGovernment where governments are driven by the innovative and intelligent use of ICT as a service provider for government activities and distribution of public information. ICT combined with latest mobile and wireless technologies can be used effectively to streamline government activities and public service delivery process to improve productivity and drastically reduce capital

expenditure, time and effort. Many governments have identified potential areas to be developed via the effective implementation of ICT based solutions that will meet the demands of the future world. The transportation infrastructure is one such area, which can be improved to provide an efficient, dependable and safe service to the general public with the integration of advanced communication technology. Appropriate adoption of technology would assist seamless administration of resources that would positively impact the country's economy.

The railway services in Sri Lanka are rendered by the Sri Lanka railways Department, which is wholly owned by the public sector of the country. The government is seeking methods to improve the efficiency of this service with the main objective of providing a better service to the train commuters. However, the effort of the government is constrained by the lack of funding and inappropriateness of the current solutions. But the development of ICT has revealed many options to uplift the railway service at a lower cost. Accurate train positioning has been a fundamental requirement to improve the efficiency of the service. The current switch based train-tracking system used by Sri Lanka Railways (SLR) supports the train controllers to manage the train operation by providing the train's location. The location data provided by this system lacks in dependability. Furthermore, the maintenance of the system accounts to a large portion of total cost incurred on the railway service. Majority of these systems (especially outside the Colombo Suburban Area) offers low accuracy in terms of indicating the location of a train to the Train Controllers. Installing the systems, which can accurately provide such readings are really expensive and the total cost of ownership is unbearable for SLR. The train safety has been an issue with the increasing number of incidents being reported that has caused death and injury. Majority of deaths on the railway involve third parties with the incursion onto the level crossings. Average train accident would cost millions of Sri Lankan rupees and these can be avoided if there is a mechanism to track the train location and speed and warn the locomotive drivers about possible safety issues. Additionally, the train commuters also face difficulties due to frequent train delays, as the administration is unable to provide accurate schedules based on train's location and speed.

The solution is a comprehensive GPS/GSM based train tracking system, which provides accurate, dependable and timely information to the controller. The in-built GPS module identifies the train location with a highest accuracy and transfers the information to the central system via GSM. The availability of this information allows the Train Controller to take accurate decisions as for the train location. Location data can be further processed to provide visual positioning using maps granting a wholesome view on train location. Positioning data along with train speed helps the administration to identify the possible safety issues and react to them effectively using the communication methods provided by the system. Additionally, the location information can be used to facilitate accurate scheduling with regard to train arrival and departure on each station. This information can also be made available for the commuters to identify any train delay in advance making this service more reliable.

### **Railway services in Sri Lanka**

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The Sri Lanka Railways Department provides long distance and intercity express, Colombo commuter, parcel and mail, freight and provision of special

charter trains. This accounts to a provision of services to 105 million passengers and transfer of 1.6 Million metric tonnes of freight per annum. The railways are a vital part of the country's transport infrastructure. As the economy grows, demand for efficient transport services increases, which the rail industry has an important role to play in meeting. The rail industry is making progress in increasing the number of passengers carried, as well as its share of the freight market, and in improving its customer focus and its levels of performance and safety.

## **Railway Today**

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In 2008, railway losses amounted to LKR 4,553 million and state bus transport losses amounted to LKR 3,554 million, giving a total of LKR 8,107 million losses on state transport. This is not just a one- time phenomenon, but has been the trend for the last few decades. The total losses from the railway alone since 1999 have been LKR 28,052 million. That means, on average, the railway lost LKR 234 million every month over the past ten years; or, to make it even more graphic, LKR 7.79 million every single day for the last ten years [1]. This depicts the current state of the railways system in Sri Lanka as for the efficiency and general acceptance of the service.

Reliability matters to the railway's customers and to the economy at large. Train delay, a common phenomenon in Sri Lanka is considered to be inevitable and an acceptable scenario. A train delay might vary from 15mins to many hours. There are occasions where this has caused disputes among the commuters and the administration but the problem still remains unresolved. Railways department maintains a fixed schedule on train arrival and departure but does not pre-update based on potential delays. As a result the commuters face many problems and waste time and energy that can be used more productively.

The provision of safe and reliable services is a fundamental requirement of the railway as thousands rely on this service as their prime mode of transportation. The railway accidents accounts to death, injury and a large cost to the government. Most of the accidents are in form of derailments, which occur infrequently but have the potential to result in a large number of casualties. The most significant contributors of these accidents involve track and signaling faults. Lack of communication between the controllers and the drivers might prevent the preliminary precautionary actions being taken to avoid such accidents. Additionally, the danger relies on the fact that there would be no mechanism to identify the potential safety issues as for the unawareness of trains speed and location.

The railways department has set itself several objectives to address this situation through a quantitative improvement of its services. It is planned to increase railway share of passenger transport from percent 5% to 10% and Modal share of freight transport from 2% to 10% by 2010[2]. Additionally, the department has identified the importance of improving the safety and efficiency of the service and has set the following objectives in its strategic plan;

- Improve cleanliness & quality of coaches / stations

- Reduce train delays by 25 % and accidents/ derailment by 50%
- Remove all speed restrictions less than 8 Km Ph
- Establish management structure based on performance evaluation and monitoring process
- Enhance the percentage of efficiency
- Put in place a methodology for utilization of public funds corresponding to specific services to make the present negative contribution in to a positive one

There're several constraints that needs to be addressed in order to achieve these objectives as this might even require complete reengineering of certain technological aspects of the current system. The main constraint of course is the lack of funding. Railways are suffering from historic under-investment stretching back for decades that could be assumed to be so for the foreseeable future as well. However, it's possible to develop effective solution that is economically feasible to the government. This would only be possible with the appropriate introduction of new technological solutions that achieve both performance and cost goals.

### **Provisions for the future**

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Setting objectives won't be adequate for the development of the railway service in Sri Lanka. There should be effective and appropriate steps taken with a vision on addressing future demands and expansion. These steps should involve further planning, extensive designing, implementation of solutions and maintaining such systems in order to sustain the service. There are several potential steps that can be taken in order to address most of the aforementioned issues associated with the railway service that in turn would assist the Railways department in achieving its strategic goals.

### **Improving Safety**

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The Railway department of Sri Lanka carries about 150 million passengers per annum and the safety of such service can never be taken for granted. Passengers are entitled to expect to travel in safety throughout their journey and the government should be committed to protect the passengers and employers form any safety issue that might rise during the journey. Effective safety planning requires a detailed understanding of key risk areas; the activities or circumstances where the safety risk to passengers, the workforce and the public is greatest. This allows resources and effort to be concentrated where they will have the greatest impact. Following are the main security issues identified in Sri Lanka;

- Infrastructure engineering issues – derailment, signaling, points and crossings
- Public behavior – Assault, objects on line, objects thrown at trains, accidents at level crossings

- Passenger behavior – Struck against fixed objects, falling from train in running
- Workforce issues – maintenance error, control errors

The main safety issues are in the form of accidents that mostly involve third parties other than the passengers and the employers. However, infrastructure and workforce issues accounts to a considerable amount safety threats identified in Sri Lanka. Most of the infrastructure issues are associated with signaling and accident. This can be addressed by developing a communication channel between the train and the control center. The control center should be able to identify the train's location and speed to recognize possible safety threats; such as collision domains, speeding and noncompliance to signals. The control center should also be able to notify the locomotive drivers of the security threat. This will allow the drivers to avoid or at least minimize the harmful consequences. New system-management technology combined with accurate knowledge of train position will give the opportunity to present drivers with advisory speeds as well as safety-critical speeds, aimed at maintaining the flow of traffic by regulating trains in advance of points of conflict so as to avoid or minimize the need to stop trains to await paths. Human intervention at control centers can lead to accidents due to human error or negligence. For an instance if the cross point calculation is done manually it can lead to accidents if an erroneous value is communicated. These problems can only be solved via an automated system, which will handle these tasks and would consequently avoid human error.

### **Improving Reliability & Availability**

The trust on the railway as a reliable service has degraded over the last few decades due to poor provision of services to the general public. This is mainly due to the frequent delays experienced specially in long distance services. A reliable railway is the single most important requirement of passengers. Delays are an unproductive use of people's time, and serious delays might disrupt their travel plans. The initial cause of a delay can be:

- An infrastructure problem for which railway department is responsible (for example, a signaling problem or a speed restriction imposed in response to a track defect);
- An operational problem for which a train operator is responsible (for example, the breakdown of a train); and
- An incident that is largely beyond the railway's control (for example, an accident involving a third party)

The signaling problems and accidents involving third parties can be minimized using a communication channel between the drivers and the control centers. The control center should be informed of the train's current position and speed that should be based on an accurate, dependable source of data. Delays can be minimized with driver advisory speeds, improved platform departure times, backed by predictive routing algorithms and supporting regulation of train movements through junctions, can ensure presentation of trains just in time to utilize a free path, rather than stopping and starting from rest when a path becomes available. None of these solutions will be possible

unless the current tracking system is replaced by a dependable and a more informative system that is capable of providing accurate train position and speeds of the entire network.

The cost of train control should fall rapidly once real-time train location systems that are suitable to the local context is identified and are implemented. It is likely that operations on most regional lines will be controlled from an operations centre, through low-cost wireless technology such as GSM, the future development of which will allow increased capacity for train control systems, regulation, and improved passenger safety services.

## **Improving Communication and Public Awareness**

Lack of information regarding train schedules, delays, and low accuracy of the schedules are to become worse within the context of expansions and would only result in more time spent on the platform, consequently resulting in public dissatisfaction and frustration. There are several constraints identified that would prevent the railways from providing accurate schedules and other information.

- The static nature of the information sources (ex: static web pages and notifications at stations)
- Deficiencies of the current tracking system

General public is made aware of the train schedules using notifications at train stations and via the official web site of the railways department. However, none of these methods will provide accurate data as for the static nature of the web site and the notifications at the station. Additionally, the deficiencies of the current tracking system impose constraints on providing accurate, dependable and timely information to the user. The switched based tracking system used by the railways department is yet to cover the entire network but would cost a considerable amount for expansion and maintenance thus, emphasizes the need of an alternative that would be more accurate and cost effective. This limits effective decision-making due to inaccuracy and would also lead to accidents.

Additional train capacity and better service performance will be the key for success, but the coherent use of technology to deliver information on train status in real time will not only improve utilization, but also offer seamless planning as well as accurate information on availability of passenger services. Further enhancements of such system would even grant passengers capabilities such as text messages informing accurate arrival and departure times and even the seating capacity of the train.

## **GPS/GSM Based Train Tracking System**

We strongly believe that the correct combination of latest information and communication technologies can provide an effective and feasible solution for the requirement of a reliable and accurate train tracking system to improve the efficiency and productivity of Sri Lanka Railways.

The solution we propose encompasses a powerful combination of mobile computing, Global System for Mobile Communication (GSM), Global Positioning System (GPS), Geographical Information System (GIS) technologies and software to provide an intelligent train tracking and management system to improve the existing railway transport service. All these technologies are seamlessly integrated to build a robust, scalable architecture as illustrated in Fig. 1.

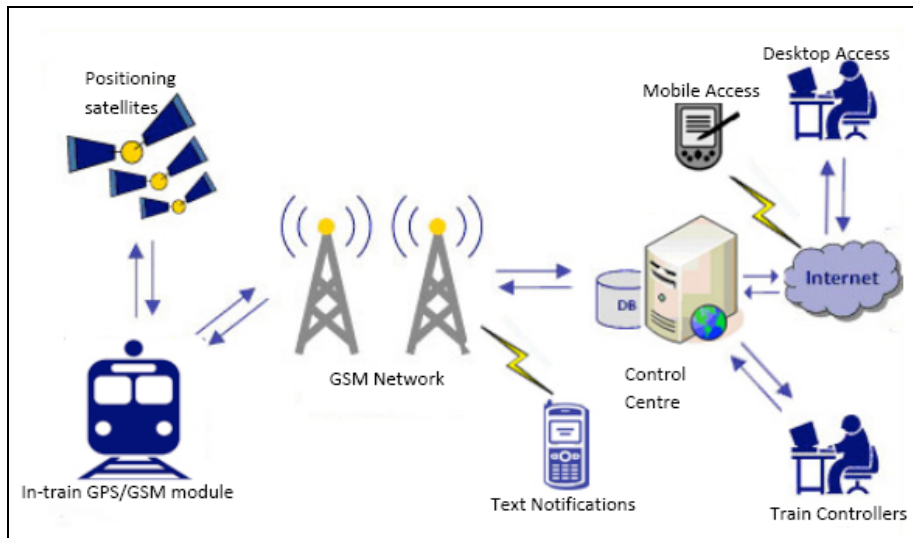


Fig. 1: High Level Architecture

The fundamental process in our system is obtaining train location using GPS technology and transmitting the data via GSM network to the central control unit for data processing and information analysis. Real-time positioning information received by the server is made meaningful and extremely useful for the end user through integration of GIS technology where the end user can better organize and utilize information from a graphical view point.

Our system consists of 3 main modules.

- The portable hardware unit (GPS/GSM train locator unit)
- Central server which handles receiving information from train locators and concurrent user requests
- Graphical User Interface (GUI) to provide services to our stakeholders

The train locator unit planted in the train is designed and implemented, considering the cost factor, size of the module, durability and low power consumption. The power supply unit of the module is a main factor which decides the feasibility of the unit, as it should sustain a seamless supply of electricity at a low voltage for the locator module to function properly. The GPS receiver of the unit is capable of identifying the latitudinal and longitudinal position and ground speed of the specific train by receiving information from the GPS satellites. The position data is periodically sent to the central server through the GSM transmitter of the module. The device is capable of storing data in a buffer at a time of GSM connectivity failure, and can synchronize with the remote server when GSM is back online. The device can also respond to commands and data calls from the remote server as per administrative requirements of the train controllers. We have chosen GSM as the communication medium between the train locator and the central server to improve availability of our system by utilizing the existing GSM network which covers the whole country. The use of GSM over GPRS



significantly improves the feasibility and availability of our system. Despite the high mobile penetration and number of mobile telecom service providers (GSM) covering the island, GPRS usage and the coverage is poor in many rural parts of Sri Lanka. Thus, selection of GSM over GPRS data communication is feasible and enables island wide service provisioning. The competition between the GSM service providers has also lead to high quality GSM services at fair rates.

The central control system includes a server for handling and processing all the position information received from train locators via the GSM network. The server automatically updates the database with latest position, speed and direction information of each train. The server carries out information processing and analyzing in order to cater for different requirements of the users of our system. The main stakeholders of our system are the railway administrators (Railway Department), locomotive drivers and the train commuters. Our main objective is to be instrumental in improving the efficiency and effectiveness of Sri Lanka Railway services by fulfilling the fundamental requirement of reliable and real time information of train positioning for monitoring and administration purposes by the Railway Department.

The end user of our system is offered with an easy to use graphical user interface for information analysis and administration tasks. The web based access and extensible mobile access to our software is designed to be intuitive for the end user to maximize the effectiveness and efficiency of our system. We have incorporated GIS techniques to provide location specific data organized in layers so the end user can better apprehend the information provided by the system. Satellite images providing visual positioning can serve as a very good background when used in conjunction with map data specifying the location. Our system essentially provides functionality for the railway administrator to monitor the progress of a particular train or a group of trains operating in a geographical area. The user can search and locate trains by the train ID, train name, current location or nearest station etc. Information such as train speed, direction can also be given along with real time train positioning data.

The train control and management process includes management of heavy traffic of passenger and freight trains, which operates in complex running patterns on the railway network. The train controller needs to ensure that passenger trains are adhering to the schedules as well to find efficient routes for unscheduled freight trains. Recording the train movements, arrival/departure at railway stations, fuel status, railway track conditions, and passenger information is a tedious task for the train controllers and would be time consuming if done manually. The accuracy of this information is very important to ensure smooth functioning of the railway service as well as to optimize resource planning. For example at a point of a railway-track failure or an accident, train controller should be able to decide on how to utilize existing resources and efficient alternative routes to ensure system availability of the railway service in that region. Thus our train tracking system can be enhanced to automate the train control and management process of the Railway Department in order to improve the efficiency and effectiveness of the railway services provided. Following is a list of facilities that can be offered by our system to automate the train control and management process.

- Automatic record keeping of train operations and events
- Functionality to generate time-distance graph for trains which can be used to control and plan the train movements
- Facility to generate user defined reports and graphs on train movements, arrival-departure at each station, schedule adherence etc.
- Facility to playback the progress of each train and events for review purposes
- Automated schedule regulation
- Forecasting functionality on train arrival-departure at different stations
- Automatic detection of over speeding, non-adherence to traffic regulations, rail-track failures, train delays etc.
- Facility to send alerts/warnings to particular train drivers on possible collisions, derailment through the system
- Automatic rail crossing control

By automating the process of record keeping of train traveling, the load of paper work on the train controller is dramatically reduced. This would also ensure accuracy and integrity of the data eliminating human error when documentation is done manually. A single entry point of data ensures there's no ambiguity of the data recorded in the system. The logged data on arrival-departure time at different stations, number of passengers onboard, freight details, signaling and fuel status at different stations, are instrumental for railway administration when evaluating performance of trains and locomotive drivers. Graphical representation of these data with ability to compare with historical data will be instrumental for the administration to take effective decisions. Various user defined reports on train activities, driver performance, passenger and freight information also support timely and accurate decision making by the administration.

Time-distance graph is vital for the train traffic regulation process. The graph gives the user a wholesome view of the train circulation, railway infrastructure state in different regions and enables the user to detect abnormal conditions and conflicts. The graph is useful for the train operator to identify traffic problems in advance and take precautions to resolve the problems.

Data mining is a method of extracting patterns from data [3]. The use of advance data mining techniques combined with complex algorithms such as neural networks, genetic algorithms and rule induction can be instrumental in identifying hidden patterns from enormous amount of data. Spatial data mining technique combines data mining with GIS to find patterns in spatial data, which could be a powerful tool for applications using geographical information such as our system. With the huge amount of data pertaining to train operations collected daily, process of information analysis using conventional methods would be a difficult task. Hence, the use of spatial data mining techniques would drastically improve the productivity and effectiveness of the train control and

management process carried out through our system.

Facility to playback past activities on the railway, enables the user to review and analyze operational situations in the past. Data mining operations can be used effectively in combination with the playback function to identify sequential patterns of particular activities and their impact on the railway traffic. For example, at an unfortunate incident of a train collision, train controllers can use the playback feature combined with the data mining techniques to analyze and identify the sequence of activities which resulted in that accident. With that knowledge, railway administrators can take necessary precautions and trigger alerting mechanisms to avoid such unfortunate accidents in future, making the railway transportation much safer.

Improving safety and availability of railway transport service requires detection and triggering of alerting mechanisms to avoid possible train collisions and other forms of adverse incidents. Constant monitoring of train location, speed, traffic conditions, rail-track conditions and adherence to traffic regulations helps the train controllers to detect potential collisions and derailments. A proper alerting framework is vital in order to avoid such adverse incidents by alerting the locomotive drivers in advance. Our system facilitates a comprehensive alerting mechanism by enabling the train controllers to send alerts/ notifications to locomotive drivers via GSM connection. The hardware unit planted in the train can be enhanced to prompt the alerts to the driver in graphical and audible forms. A LED display unit and an alarm bell to signal adverse conditions can be integrated with the hardware unit to provide a complete alerting framework. The unit can be further enhanced to support voice communication between train controllers and locomotive drivers in order to provide guidance and important messages to the particular driver. This would also enable locomotive drivers to contact the control unit at a state of emergency. Furthermore the system can be incorporated to significantly improve safety at railway and road intersection points. Over the years, many road accidents have occurred at railway crossings imposing a critical safety threat to both train commuters and passengers in vehicles.

Such accidents are caused mainly by the unreliability of the safety mechanisms such as blocking arms and signal lights used at the crossing point. Thus our system can be extended to improve the reliability of such safety mechanisms by synchronizing the railway crossing control process with the incoming train's position. We can provide accurate real time information on train position, speed and length of the train to synchronize the functions of rail crossing with the train movements. The productivity of the service can be significantly improved by providing accurate predictions on approaching train at the rail-road crossing and displaying amount of remaining time to clear the crossing from train traffic. Alarm triggers to alert road vehicles approaching too close to the rail-road crossing at a point of train approaching, can also be incorporated to improve the effectiveness of our solution. Thus the system is instrumental in improving safety of both railway passengers and people crossing rail-road cross points.

Integrating an intelligent forecasting mechanism on arrival-departure time at different railway stations can further enhance the efficiency and productivity of our system. Train schedule is inevitably subject to train delays which can occur due to various reasons such as excessive train load, rail track failures, train

traffic, adverse weather conditions etc. A number of operational parameters such as railway traffic, train priority, efficient routes, and railway infrastructure conditions have to be taken into consideration to accurately forecast train arrival time at various stations. Here also data mining with other complex algorithms can be instrumental to provide accurate forecasting on train arrival-departure at stations. The train schedule regulations are automatically updated and stakeholders can be notified.

One of the main purposes of our system is to facilitate accurate public information distribution with regard to railway services and operations. Thus, our system can be incorporated to design and implement innovative Passenger Information Systems (PIS) based on real time information of train positions. LED-Display panels put up at railway stations can display arrival-departure time of each train enabling the public user to make informed decisions on their journeys. Route number, destination of the arriving vehicle and waiting time can be displayed with real time information. With accurate forecasting of train arrival-departure at stations, Railway Department can improve the loyal customer base and also attract new passengers to railway transport service by winning their trust and reducing user uncertainty of using public transport facilities. The user experience can be further enhanced by introducing information Kiosks which can provide information to travelers in an intuitive and interactive manner to make informed decisions on selecting train routes and departure time. The interactive kiosk can be used to obtain travel information such as alternate routes to specified destination, route details on the railway map and latest information on train schedules etc. As a marketing strategy, information regarding the particular city, culture and commercial activities can also be provided to the user through the kiosk. Another extension of the PIS system is delivering real time train information to handheld devices such as mobile phones and PDAs. With the increasing interest on mobile applications, access to latest train schedule information via mobile connection can be influential for improving customer base of the railway service. Easy to use mobile applications can be designed and implemented to enable train commuters to easily subscribe to our service and obtain latest train schedule information via mobile devices. Reliability and customer loyalty of the railway services can be significantly improved by taking such action to improve accurate public information distribution of the current status of railway services.

## **Conclusion**

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After seeing many advancements and changes in the location tracking technology, Sri Lanka Railways now has the ability to pin point the location and other attributes of an operational train in an economical accurate manner. Thus it is visible that to keep up with the today's demand for information and to comply with the citizen centric governance, technological advancements is essential for a 3<sup>rd</sup> world country, as after all the deciding factors of a country's success would be on the how collaborative and duplex the governance framework in terms of seamless information flow of accurate and timely information between governance ecosystem.

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