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A Software Architecture That Can Be Used for Reliable Socio-Economic Relations in Pandemic

Salgınlarda güvenilir sosyo-ekonomik ilişkiler için kullanılabilecek bir yazılım mimarisi

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The epidemic, spread around the world and known as Covid-19, negatively affects social and economic life. Humanity has been caught unprepared for this epidemic, as there is currently no cure. In the case of epidemic, social and economic relations that people like shopping, travel, market should interact must be safely implemented. In this context, the measures applied under the control of security officers require additional burden on the state. Curfews and partial quarantines restrict the lives of uninfected and isolated people and bring the economy to a halt. In this study, a software architecture that can be used in cases of epidemics is suggested. In the approach that uses big data and graph database, it is assumed that every individual or business is included in the application by the state. In this way, each individual can be represented with a unique identity. A four-state health code is used to represent the level of the disease. Three of these codes, which will be obtained by using e-government services, big data approach and mobile network services, represent situations where a person is a positive case, is completely healthy and is in contact with a positive case. The last code will be used to report individuals using the application, but to a particular business or other individual. It will be used to identify and report users who do not use the application or do not match the barcode. Within the scope of the study, software architecture design and mobile application interface were realized, and the approach presented through simulation study and sample scenarios were verified.

Keywords: *Big data, Covid-19, e-health, Pandemic*

Dünya genelinde yayılan ve Covid-19 adı ile bilinen salgın, sosyal ve ekonomik yaşamı olumsuz etkilemektedir. Halihazırda bir tedavinin olmaması nedeni ile insanlık bu salgına hazırlıksız yakalanmıştır. Salgın durumunda alışveriş, seyahat, market gibi insanların etkileşimde olması gereken sosyal ve ekonomik ilişkilerin güvenli bir şekilde yerine getirilmesi gerekmektedir. Bu bağlamda güvenlik görevlileri kontrolünde uygulanan tedbirler ise devlete ek yük gerektirmektedir. Sokağa çıkma yasağı ve kısmi karantinalar ise hastalık bulaşmamış ve izole insanların yaşamlarını kısıtlamakta ve ekonomiyi durma noktasında getirmektedir. Bu çalışmada salgın hastalık durumlarında kullanılabilecek bir yazılım mimarisi önerilmektedir. Büyük veri ve graf veritabanı kullanan yaklaşımda her birey ya da işletmenin devlet eliyle uygulamaya dahil edildiği varsayılmıştır. Bu sayede her birey benzersiz bir kimlik ile temsil edilebilecektir. Hastalık düzeyinin temsil edilmesi için ise dört durumlu bir sağlık kodu kullanılmaktadır. E-devlet hizmetleri, büyük veri yaklaşımı ve mobil şebeke hizmetleri kullanılarak elde edilecek bu kodlardan üç tanesi kişinin pozitif vaka olması, tamamen sağlıklı olması ve pozitif vakayla temaslı olması durumlarını temsil etmektedir. Son kod ise uygulamayı kullanan ancak bireylerin belirli bir işletme ya da diğer bireyi raporlaması için kullanılacaktır. Uygulamayı kullanmayan veya barkod ile uyuşmayan kullanıcıların belirlenmesi ve raporlanması için kullanılacaktır. Çalışma kapsamında yazılım mimarisi tasarımı ve mobil uygulama ara yüzü gerçekleştirilerek, simülasyon çalışması ile örnek senaryolar üzerinden sunulan yaklaşım doğrulanmıştır.

Anahtar Kelimeler: *Büyük veri, Covid-19, e-sağlık, Salgın*

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1. INTRODUCTION

Covid-19, which spreads globally, is the most important agenda of the world today. This virus, which we has not yet become clear from the exit point and how it is transmitted to humans, can be transmitted very easily through the respiratory tract in close contact. The absence of symptoms in the 14-day incubation period is one of the biggest risks of this disease. Coronavirus, which enters the cell and attacks the lungs, causes death due to respiratory failure, especially in people with certain age groups and chronic conditions. This epidemic, which is spred suddenly all over the world, is especially dangerous because it is easily contagious. Individuals with a strong immune system survive the disease or can be a carrier without any symptoms. In some cases, it is known that some carriers infect the disease by hundreds of people and cause death to those who have been infected although there is no negativity in themselves (World Health Organization, 2020).

Today, people can be in intensive contact with other individuals in the place where they live, neighborhood, business relations, market and shopping centers. In this respect, Covid-19 has an exponential potential that increases exponentially considering its contagiousness. In order to stop the spread, rules such as travel restrictions, restriction of the risk group individuals' exit, distance education and training, temporary closure of places such as barbershops and restaurants, and most importantly, compliance with social distance rules must be followed. However, this situation affects both social life and the economy considerably. Moreover, there is a similar situation across the world, where the number of cases is expressed in millions. For this reason, Covid-19 is not only a virus that threatens public health, it also has negative sociological, psychological and economic effects on societies and it is inevitably foreseen that these economic effects will deepen in the long run (Chinazzi et al, 2020:395-400)

In addition, due to the fact that viruses can evolve from person to person due to genetic differences and other reasons, the current treatment and antibodies do not work in new types of viruses, because of the fact that viruses, which were previously seen only in animals and which were not likely to be transmitted to humans, can now pass from animals to humans. There is always a potential danger that similar epidemic risks will continue and negatively affect community life (Anderson et al, 2020:931-934).

Various researchers in all countries are working hard on the protein structure of the virus, antibody development and ultimately vaccine / drug production for the definitive treatment of the disease. It has been observed that drugs currently used in the treatment of certain diseases, such as malaria, reduce Covid-19 recovery time. A similar finding was noted by Australian researchers that drugs used to treat parasites in animals and humans largely destroy the virus in the laboratory. Some countries have announced that when the prototype vaccine is under development, and in the near future, vaccines can be tested on humans. However, a very near future cannot be anticipated in order to find an effective and definitive treatment, to detect possible side effects and harms on people and to start mass production (Xu et al, 2020:1-3).

Various studies are being carried out in many sectors and disciplines that can be directly or indirectly related to combating widespread epidemics (Wigginton et al, 2019:1-28). In the medical field, the development of test kits with higher accuracy and rapid results, and the development of new generation respiratory devices for the use of intubated patients with acute respiratory difficulties are exemplary studies in this field. It has been found that the virus cannot cling to clean surfaces and can live for hours in inanimate environments, thereby transmitting directly from common objects and surfaces in addition to direct human contact situations. Therefore, it is necessary to spray and disinfect such common areas and indoor spaces. Instead of this costly process that needs to be done periodically, the use of high efficiency filters requires high energy power. Wigginton et al. (2019) have developed a device that is harmless to human health, with a static electromagnetic effect created by sending pure oxygen to the air with an electromagnetic reactor and heat-free plasma treatment, and destroying 99.9% of the bacteria under 1 second. With the reduction of the size of this device and becoming a wearable technology, it can replace the virus and protection masks used today.

In addition to those mentioned above, the state develops some protocols for certain institutions and society and ensures that they act in an appropriate manner. These are case management in 2nd and 3rd level health institutions, follow-up for passenger and flight attendants, outpatient/emergency case management, evaluation of Covid-19 contact healthcare professionals, discharge and isolation rules in Covid-19 patients (T.C. Sağlık bakanlığı, 2020).

In the software area, studies such as developing artificial learning algorithms for determining the image-based infection on the lung images, measuring their level and following the recovery process are carried out (Shan et al, 2020:1-28 & Gozes et al, 2020:1-19). In addition to the development of such algorithms, there are other benefits that can be obtained from the software industry in the event of a pandemic. In this sense, China has effectively used Wechat social messaging software in outbreak management. In China, the Wechat program, which is a voice and text messaging program, has been integrated with the health code and has been used to instantly determine the health and safety status of people in areas such as metro (Liu et al, 2020:1-2). If the person is in contact with Covid-19 or a positive person and has not completed the incubation period, they cannot use these areas. In cases of violation or fraud, there are heavy sanctions.

For a similar purpose, a pandemic management system has been developed. There are two basic features in the developed system, namely the panic button that provides notification and direction of health teams. It provides notification to other individuals at the last location of the individual whose notification system is Covid-19 (Hurriyet, 2020).

In this study, a software architecture was created that uses event-driven employees, big data and graph databases, which will enable a more secure and auto-controlled management of state-implemented measures for pandemic management. The aim of the study was to enable individuals to autocontrol themselves and against each other in case of epidemic, the state to track individuals more effectively using technological facilities, to perform the filection process more quickly in positive case situations, and to conduct socioeconomic relations more safely.

2. METHODOLOGY

The outbreak management software to be used in the outbreak proposed in this study has two different types of actors, state and individual. The general block diagram of the proposed approach is given in Figure 1.

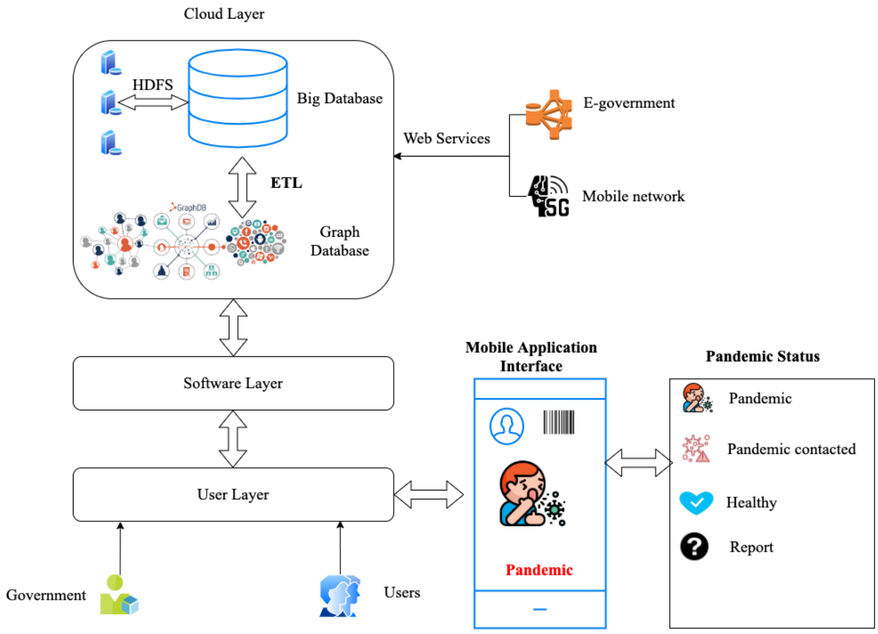


Figure 1. Block diagram of the proposed approach

The proposed approach is a 3-layer architecture. The architectural layer includes web services and a database. The components and their purpose are described as subsection as follows, respectively.

2.1. E-government

In positive case situations, it is very important for the process of filection to find out the source of the disease and to isolate and isolate individuals who may be in contact. Information such as family tree, address information system and the person's education and profession in the e-government application can be used for the rapid acquisition of people with whom they may be in contact. The main purpose of the application is to assign an automatic code to the people who are contacted during the incubation period, forcing them to quarantine or following them (e-devlet, 2020).

2.2. Mobile Networks

In the social life of the person, location information is needed in order to be able to determine other people who interact with the outside environment such as park, shopping center and market in case of need. Location information can be obtained from the mobile network provider. Mobile network services will be needed in order to identify the locations of a positive case other than the information that can be obtained from e-government web services and other individuals in these locations.

2.3. Big Data

In the proposed approach, it is necessary to use two database management systems that work integratedly. The first of these is a NoSql based open source database, such as MongoDB, which can be established in a suitable parent-child relationship for the big data infrastructure and supports distributed architecture (Kang et al, 2015:485-497). This database contains basic information such as age, occupation, place of residence, location information on the move and action information such as shopping, being in the park, traveling.

2.4. HDFS

The calculation complexities of the inquiries to be performed on big data are high. The distributed query service HDFS offered by Apache minimizes this computational complexity. There is a need to make distributed computing needs such as storing large amounts of data, reading, updating effectively.

2.5. Graph Database

The second database used is the graph based database (Robinson et al, 2013:1-238). Graph databases consist of nodes and edges. Within the scope of this study, people who have a graph database pandemic and/or who have been in contact with the pandemic or have not completed the quarantina period due to any action, can be identified effectively, show more understandable and CRUD (create: record creation, read: record reading, update: record update, d: deletion) provides easy database operations. The purpose of the application is to effectively represent other individuals with whom the person is related on the graph database. In the Graph database, nodes represent entities such as person, workplace and home, and edges represent relationships between nodes. An example graph database designed for implementation is shown in Figure 2.

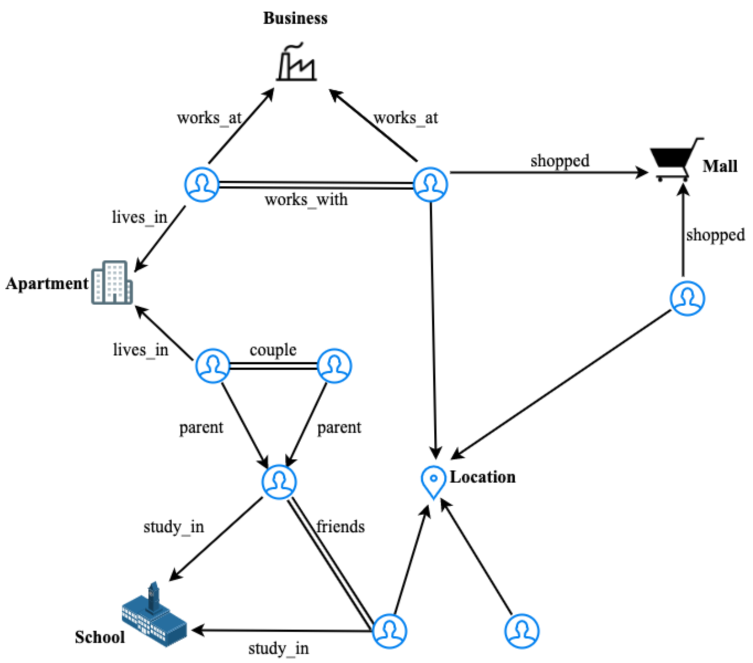


Figure 2. Graph database structure of the proposed approach

2.6. ETL

Data for each individual in an application such as e-government is kept in relational databases. Graph databases represent these relationships as nodes and relationships, as shown in Figure 2. The ETL (Extract Transform Load) layer will be used to extract, transform and load the information from the relational database. Possible nodes and relationships that can be found in the Graph database are summarized in Table 1.

Table 1. Graph database node and relationships

Assets	Node/Relationship	Secondary relationships	Comment
People, Location, School, Mall, Workplace etc.	Node		All of nodes
lives_in	Relationship	lives_with, couple, neighbor	Lived address
works_at		works_with	Business friendship
shop, visit		be_together	Being in the same location
use		use_with	Traveling together etc.

2.7. Software Layer

The software layer is time and event driven. Any individual will engage in any action and take time in specified periods, and will run a risk determination algorithm for all other individuals with which the individual is associated, and will generate regular reports and reports. There are two main actors in the user layer. The user layer simply has to identify itself with a unique id or data matrix such as tc identification number on its mobile application and must show its own health code on the phone in case of market, bakery, metro, intercity transportation. These codes are a categorical variable consisting of a total of four conditions, symbolizing a person's pandemic health status (Madakam et al, 2015:164-173).

2.8. User Layer

The last layer in the proposed approach is the user layer that represents the mobile application layer of the users. In this layer, individuals can see the health status of themselves and the individuals with whom they interact / will be able to report and report as suspicious cases as the last option. All possible codes and example usage scenarios are given in Figure 1, respectively.

2.8.1. Pandemic

The first code is a value that can only be assigned to the user by authorized institutions such as the state, and is only given in cases where the test result is positive and detected by health institutions. People who continue to be treated at home because their symptoms are improving will continue to have the same code during quarantina, as the isolation rules must be followed. Those who are fully recovered and discharged will be labeled as safe again.

2.8.2. Pandemic Contacted

People who are directly and indirectly in contact with a positive case and who have not completed the incubation period will be identified automatically by the algorithm that runs on the software layer.

2.8.3. Healthy

This code shows that the person is completely safe. Users who are included in the system and have no relation with the pandemic have this code by default. If a new user is included in the system, the graph database is scanned and this code is assigned if there is no risk by scanning the relationships with positive cases in the default quarantian period. In addition, users who have two other codes but have recovered and have completed the quarantina period will have this code again.

2.8.4. Report

This code will be used for purposes such as fraudulent application (use of a fake data matrix, no person it claims) or reporting of a business that has not obtained a data matrix for security reasons. On the other hand, using the e-government application, the data matrix production can be produced in a way that includes unique and basic identity information for each individual. Thanks to the proposed approach, safe people can continue their daily routines safely without being affected by socio-economic conditions, potentially dangerous people can be easily identified and help to isolate them from the community and common areas.

Below are two example scenarios that symbolize the operation of the system in Figure 3. In the first scenario, which is given as an example in the figure, the person with the positive case wants to shop. Security officers will be able to block and report this person because it is very risky. In the second scenario, one of the two individuals living in the same apartment is a positive case, those living in the same place should be isolated. Therefore, it is automatically labeled as "Pandemic contacted" by the system. In order for the person to appear healthy again, he / she should spend the incubation period and/or go to the health institution and have a test. In the third scenario, a completely safe interaction is seen. In the last scenario, the use of reporting is seen for the necessary situations.

The examples given in the figure will provide scenarios that can work in both directions and can be used for almost any situation with a common software architecture. For example, in the case given in the first example, while the business is reliable, the person who wants to shop can be insecure, the business owner can see the person's status and interact, otherwise they can report it. A similar example scenario can be used for bus and metro travel. Officers or barcode readers in the turnstile do not allow non-healthy users to travel and produce notifications for isolation of people in the environment. These and similar scenarios are reproducible. For malicious cases, there will be a reporting entry in the system. It may be reported by other users due to reasons such as non-compliance with the hygiene rules of the person, absence of the person / business he claims to have suspicious contacts. This option will work in a logic similar to the foresquare mobile application (Noulas et al, 2011:1-4). The relevant enterprise, staff or other users who come into contact with the person will be able to rate and report those personnel. In this case, the system will generate a notification based on the opinion of the majority of other users and provide autocontrol for the person concerned, forcing people who do not comply with hygiene and health rules to take necessary measures. In this context, the main motivation of the system is to facilitate the work of the healthcare teams by finding the contact persons automatically and quickly thanks to the software.

Figure 3. Example usage scenarios for the proposed approach

A brief explanation of the health codes, the actor to which the code is given, and the necessary conditions for giving the health code are given together in Table 2.

Table 2. Health codes for proposed approach

Code	Short description	Authority	Necessary Conditions for Giving the Code
Healthy	Person/business is completely safe.	Authorized healthcare institutions.	- People who are not in other situations. - Those who have recovered and have completed the quarantine period.
Pandemic	The person / business is completely insecure.	Authorized healthcare institutions.	- Cases with positive test results with ongoing treatment.
Pandemic contacted	The person / business is insecure.	System.	Following are the positive cases, family members and incubation period; - Neighborhood - Location based contacts - Work friends - Other actions (travel, shopping etc.) - Those who come into contact with the contacts (the level of depth will be determined recursively.)
Report	Person/business makes hygiene/application violation.	All users.	- Not following the hygiene rules - Not being the person / business he stated - Violation or fraud - Other suspicious situations

Below is an example scenario for event-driven programming approaches in Figure 4. In case of any notification, the default depth level 1 is selected on a recursive basis, and all other individuals are updated, and the required health codes are changed, and information is shared with sms / notifications. If the health status is "Pandemic", the update program informs all the people who are in contact with the incubation period by assigning "Pandemic contacted" according to the selected depth level, in this case, the codes are not changed until the incubation period expires and they are expected to remain in isolation. In case of a trigger action, the update program works by updating the database and sending notifications to the users affected by this action. Users affected by the action can be selected according to the level of depth. When the depth level is selected as default, the affected user is selected and the notification is generated by changing the code of the nodes that interact with this node (neighbors, colleagues, family members). The second way of reporting is to determine the locations of the person in the incubation period in case of a positive case and to notify the people close to these locations. When the depth level is increased recursively, those who come into contact with the persons who are in contact will also be detected. In the example figure 4, event-based and location-based pandemic management usage is given.

- *Event-based management:* In case a citizen is a positive case, it includes cases where the graph database relationships are quarantined (such as those with whom they live and their colleagues with working in same office) by etspit according to the dynamic depth.
- *Location-based management:* In case of a positive case of a citizen, it covers the cases of taking necessary measures for the safety of other citizens in that location by using mobile network services.

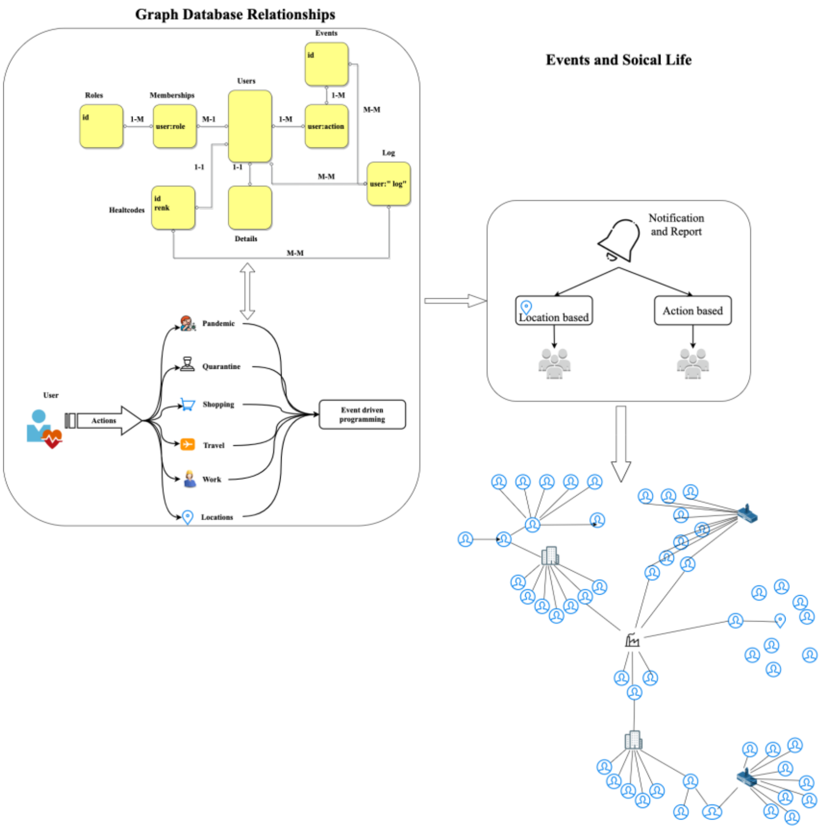


Figure 4. Location and user action based pandemic management approach

3. DISCUSSIONS AND FUTURE WORKS

The architectural framework, which helps establish safe socio-economic relations to be used in epidemic situations, offers three main contributions to this end. The first one is the location-based approach given in Figure 5. The location of the user whose test is positive is found in the incubation period retrospectively, and the users will be informed by assigning an Orange code according to the selected distance and finding time threshold values. In the figure on the far right, an example scenario is given that deals with travel action. The person traveling with the positive case is labeled with the Orange code. When the depth level is increased, individuals who come in contact with Orange can also be assigned an Orange code, where Green, that is, shown reliably, is related but not contact. It is assumed that e-government integration, users' location services are open and internet-connected smart devices and information entries are made for the application to work as it can be ideally defined. Open source technologies that can be used for software architecture are given in Table 3.

Table 3. Tools used for software technology of the proposed approach

Big data	Programming environment	Data base	Graph database	Graph query language	Web sevices	Mobile application
Hadoop (Lam, 2010;1-336)	Python (Oliphant, 2007:10-20)	MongoDB	Neo4j (Vukotic et al, 2014:1-304)	SparQL (Robinson, 2013:1-238)	Json (Fernandes et al, 2015:16-19)	React Native (Eisenman, 2015:1-242)

Below is an example scenario for location based notification in Figure 5. The figure shows the locations on the left where a positive case is in the duration of the disease. On the right, other people in the same location are shown in orange and labeled "Pandemic contacted".

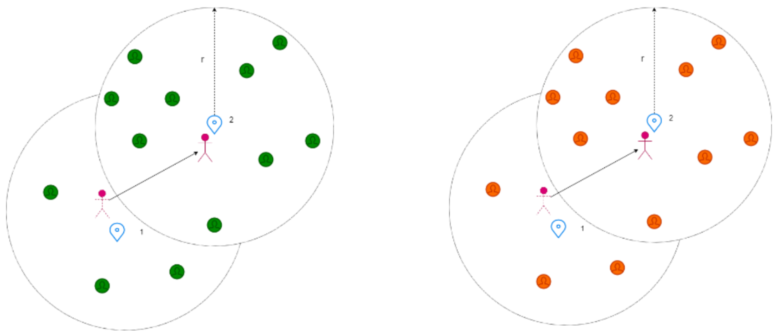
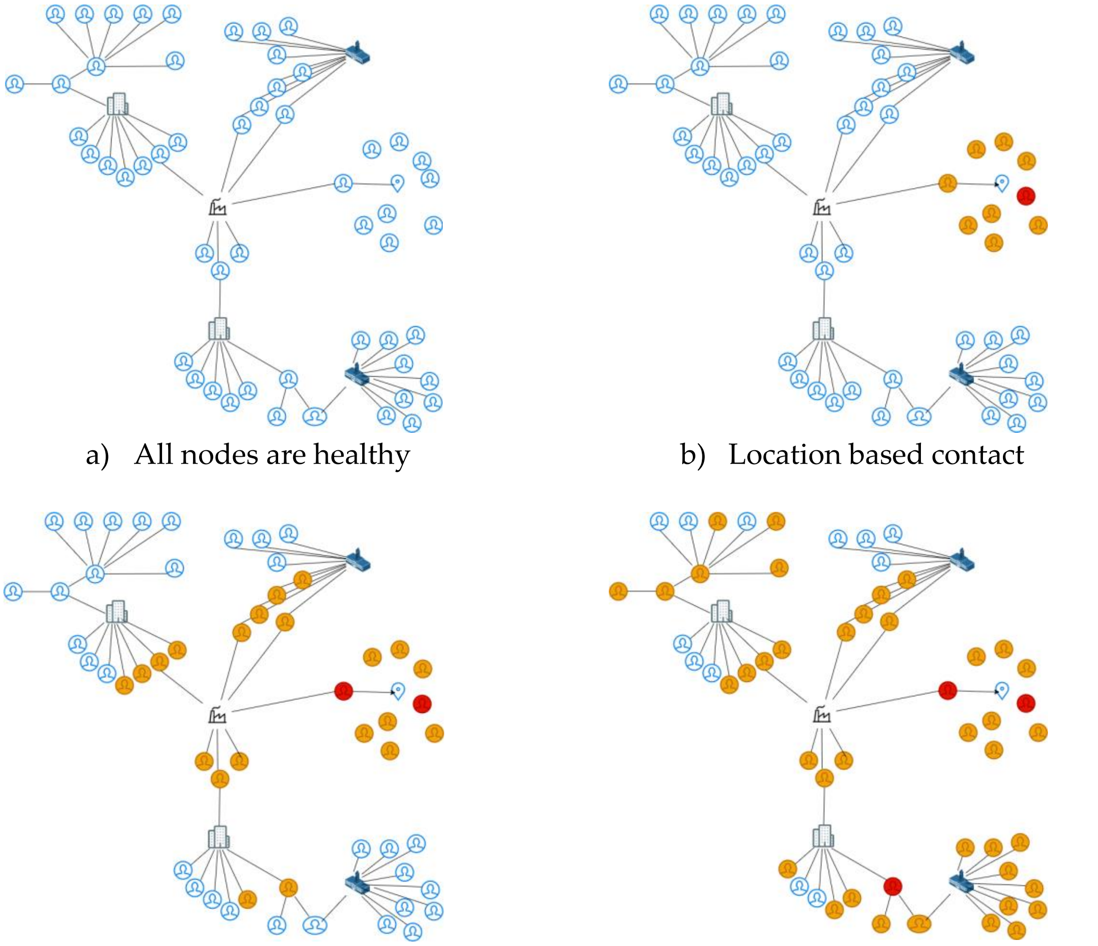


Figure 5. Location-based interaction and information of the proposed approach

The simulation study produced with synthetic data is shown in Figure 6 below. In the figure, the nodes drawn by ETL from the relational database produced with synthetic data are shown graphically. In the first way, all nodes showing people are assumed to be “healthy”. In the simulation study, positive cases were randomly selected and shown in red. Nodes associated with randomly selected nodes in the other three ways are also labeled "Pandemic contacted" and are shown in orange. In order for the contacts to be healthy again, they must have a test or fill the isolation period. In the first scenario, all nodes are healthy and accepted as the initial state. In the second scenario, one node is randomly selected as "Pandemic", and the status of all nodes in the same location as this person is labeled "Pandemic contacted" by the system and is shown in orange. It is assumed that the mobile network location service is running in order to realize this scenario. In the third scenario, a node that is in contact with the position based on the isolation time is labeled as "Pandemic". In the third scenario, people living together at the same address, people working in the same department and classmates at the same school are automatically labeled as "Pandemic contacted" by the system and shown in orange. In the fourth and last scenario, if a node is more positive than those living together, schoolmates with whom it is in contact are also labeled as "Pandemic contacted". The worst scenario in the proposed approach is that all individuals are somehow related to each other. In this case, the system will tend to realize the worst scenario and the number of faulty individuals labeled "Pandemic contacted" will be too high. However, in the proposed approach, it is assumed that the information such as address, department, education information of the person is complete and detailed in the database. In this case, the relationships on the graph database will be more accurate, the proposed approach will work ideally and produce less erroneous "Pandemic contacted" results.



a) All nodes are healthy

b) Location based contact

c) New positive case from location-based contact

d) Identification of those who are in contact with the new positive case

Figure 6. Sample simulation studies of the proposed approach

It is aimed to project this work and put it into practical application in the future. Thus, in cases of epidemic diseases, based on the level of risk, in cases where curfews and regional quarantine are not required, individuals, employees and businesses can establish safer socio-economic relationships, violations of rules or fraudsters can be reported, most importantly, using the location and graph database of those who are in contact with positive cases. A software architecture has been developed that can be taken quickly and effectively and measures such as early detection can be taken quickly.

The differences of the proposed study from health codes such as HES (it is a health code shows that the risk level used in turkey and measures for pandemic, HES 2020), which indicate the risk group used in our country today, are as follows. Although both contain common purposes and are similar, HES code is a health code that is valid for a certain period of time and indicates the risk group. In this context, the individual who has the HES code as a positive case is already aware of his / her situation. The main purpose here is to restrict the actions of someone with a positive case. In addition, the method proposed in the study aims to ensure the safety of all persons who may be in contact with the positive case, according to the level of criticality. Moreover, the approach suggested in the study will be able to create dynamic meaningful relationships by using big data and graph database relatinships, thus, it will be sensitive to both event and location based and retrospective actions (travelling, shopping). Finally, in a possible epidemic and similar situations, individuals and locations to be restricted according to the depth to be selected with the recommended approach according to the level of criticality can be selected recursively.

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