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RFID and RTLS-Based Human Resource Monitoring System

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Authors' contributions

This work was carried out in collaboration between all authors. Author ABA designed the study and conducted all laboratory and experimental studies. Author GBI conducted the literature review with author ABA, created the first draft and performed the statistical analysis. Author OCA supervised the research. All authors read and approved the final manuscript.

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Abstract

Human resources are indispensable assets as well as the livewire of any organization. For the attainment of set goals, every organization must device adequate, effective and efficient means of managing its human resources. Keeping log of personnel arrival and exit times as well as in and out movements are valuable tasks that promote objective decision on human resource performance evaluation. This paper reports on the development of a Radio Frequency Identification (RFID) and Real-Time Location Tracking System (RTLS)-based real-life personnel monitoring system. Real Time Location System (RTLS) based approach was used for accurate and reliable estimation of the distance and coordinate location of personnel at any instant. The simulation was performed on Dell Inspiron 1525 system with Alien ALR-8800 RFID readers and passive RFID tags operating at 865-867MHz frequency on Windows 7 platform. Java programming language and NetBeans IDE 7.2 on JDK1 7.0 (Java Development Kit) served as the front-end while My Structured Query Language (MySQL) relational database and PHP5 served as the back-ends. Analyses of the results of case studies of real-time data on the arrival and departure times, availability period, among others for some selected personnel of a unit in a Nigerian University show the adequacy and the feasibility of the proposed system for a reliable real-life personnel monitoring and control.

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1 Introduction

The major resources of a corporate organization used for achieving set goals and objectives are human, machine, money and time. In the era of knowledge economy, organizational success hinges on the performance of human resources (HR) and its improper procurement and management has led to several failures including under utilization of the other resources and poor performance [1]. Human resource is the adaptive mechanism for determining how an organization responds to the competitive environment and focuses on strategic initiatives like mergers and acquisitions, talent management, succession planning, industrial and labor relations and diversity and inclusion. In startup companies, HR's duties may be performed by a handful of trained professionals or even by non-HR personnel. In larger companies, an entire functional group is typically dedicated to the discipline, with staff specializing in various HR tasks and functional leadership engaging in strategic decision making across the business [2-3]. HR has shifted its emphasis to knowledge sharing and strategic workforce analysis while retaining its significant contribution in the strategic management of every organization. In line with this, HR data are being used for achieving cost savings and unique competitive advantage in all core management aspects comprising planning, mentoring, organizing as well as controlling due to its uniqueness and capability to convert the other resources into tangible output (product/service) [4]. Human resource is also one of the most important factors for providing flexibility and adaptability to organizations [5].

Human resource management (HRM) is the management of an organization's workforce or human resources and it is responsible for the attraction, selection, training, assessment, and rewarding of employees, while also overseeing organizational leadership, culture and compliance with employment and labor laws. It has been noted that managing people is more difficult than managing technology or capital [6-7] and firms with efficient and effective system for managing their human resources would have sustainable edge over others. The traditional means of monitoring and controlling human resource in the public service include the use of Attendance Register (AR) and Movement Book (MB). AR is used to monitor time of arrival and departure of employees while MB is engaged for an employee to sign whenever he or she is leaving his or her duty post. The traditional methods are unreliable for assessment and performance evaluation due to their susceptibility to human influence and manipulations. Based on this, automated systems are required for adequate and controllable human resource management. The author in [8] identified employment security, selective hiring, self-managed teams/team working, high compensation contingent on organizational performance, extensive training, reduction in status difference and sharing information as the best HRM practices. Key practices which support service organizations quality strategies include careful recruitment and selection, extensive remuneration systems, team work, training and learning, employee involvement and performance appraisals with links to contingent reward systems. Economic change, technological change, national culture, industry/sector characteristics, legislation and regulations, globalization and organizational structure are the factors affecting these practices [9]. HR practitioner have relied on Harvard, Michigan, Guest and Warwick models for effective human resource management. The Harvard model developed by the authors in [10] works as a strategic map and strives at employee commitment. With this model, personnel are required to be congruent, competent and cost effective. The Michigan model was highlighted by the authors in [11] and focuses on the management of people in the same way as other resources while selection, monitoring, appraisal, development and rewards are geared towards organizational performance. The comparative model by the authors in [12] holds that HRM strategies like differentiation and innovation focus on quality and cost reduction lead to better training, appraisal, selection, rewards, job designs, involvement and security and consequently, increased quality outcomes, commitment and flexibility. The Warwick Model in [13] emphasis analytical approach to HRM and recognizes the impact of the role of the personnel functions on the human resource strategy content by mapping and identifying the inner (organizational) and external (environmental) contexts. Present day Human Resource Management System (HRMS) interconnects human resource management (HRM) and information technology for the reduction of the workload of managers and automate their administrative activities. HRMS helps firms improve organizational behavior on staff commitment, competency, flexibility and staff performance [14]. A sound

HRMS requires effective management practices that are directed towards efficient management of human resources and ensuring that the resources are employed for the fulfillment of organizational goals [15-17].

2 Electronic Personnel Monitoring Techniques

Electronic monitoring of personnel is the computer-based collection, storage, analysis and reporting of information about personnel' productive activities [18]. Businesses have capitalized on Call Monitoring (CM), Video Surveillance (VS), Computer Monitoring (CM) and Real-Time Location Tracking System (RTLS) for the advancement of technology to promote electronic-based monitoring and controlling of employees performances. Call monitoring involves listening to live phone calls and recording one's observations. This technique is usually useful for monitoring employees who are in the customers' relations department and help desks of organizations. Video surveillance is the viewing of employees through the use of various video cameras that are located in plain sight or secretly hidden from the employees and it is used where there is no reasonable expectation of privacy [19]. Computer-based monitoring is the use of computerized systems to automatically collect information about how an employee is performing his or her job [20]. Computer-based systems have been developed for monitoring employees' personal use of the e-mail, certain key strokes a worker may hit, the errors made and the time and length of internet access [21-22]. Real-time location system (RTLS) is a local positioning system that tracks, identifies and collects (passive or active) the location of objects in real time. It uses simple, inexpensive badges or tags attached to the objects to receive wireless signals to determine their locations. Existing RTLS solutions include GPS-based location tracking (mostly used for outdoor sensing), Bat Ultrasonic Location System (BULS) (which uses radio transceiver, controlling logic and an ultrasonic transducer to function) and Cricket Location Support System (which uses a combination of Radio Frequency (RF) and ultrasound technologies to provide a location-sensing solution). Others are Wireless LAN, which pervasively emits a signal that is picked up by access points) and Ultra Wide Band (UWB), which is one of the recent works in field of RTLS [23].

2.1 Radio frequency identification (RFID) technology

Radio Frequency Identification (RFID) is a form of automatic identification data capture that provides for visibility of shipped and received materials in the form of information technology. It has been used in electronic toll collection, animal tracking, and factory automation ([24]). It requires a wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object for automatic identification and tracking ([25]). A modern RFID system is shown in Fig. 1 [26]:

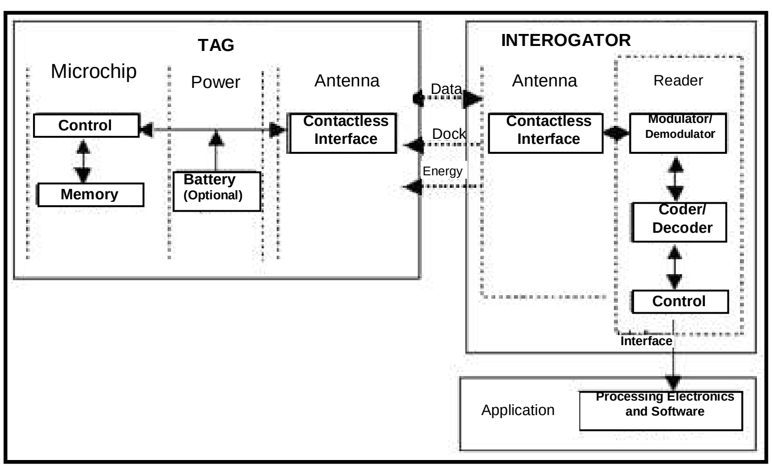

Fig. 1. RFID system components

Tags may be powered by batteries, electromagnetic fields or local power source. They contain electronically stored information which can be read from several meters (yards) away, do not need to be within line of sight of the reader and may be embedded in the tracked object. Typically, they composed of a microchip for storage and computation, and a coupling element, such as an antenna coil for communication. Tags are classified into active, passive and semi-passive categories. An active RFID tag is equipped with a power source for circuitry and antenna and support readability from a distance of one hundred feet or more as well as capability to have other electricity-based sensors. While a passive tag is powered by the reader based on the inductive coupling with the antenna and can only be read at very short distances, the circuits in semi-passive tags are powered by batteries and they reflect (rather than transmit) RF energy back to the tag reader. Depending on the application and operating conditions, there may be a multiplicity of readers to fully service a specific area. Overall, the reader provides bidirectional communication with the tags, initializes the processing of received information and establishes connection to the server that links the information into the enterprise.

3 Related Works

The authors in [27] presented an HR recruitment system. The system focuses on reducing the cost and biases that are associated with recruitment exercises. It however lacks platforms for monitoring and controlling personnel development, productivity and behavior patterns. A neuro-fuzzy expert system for the evaluation and objective assessment of personnel performance is presented in [1]. The system eliminates all forms of sentiments and biases in the judgments of HR professionals' profile and productivity on the organizational goals. The system used standalone approach thereby limiting its availability and access. In [28], an indoor location sensing system that used RFID and leveraged on the development in wireless and mobile technologies is presented. The system used active RFID readers, tags and nearest neighbor-based algorithm to function while bulkiness and standalone status restricted its optimum performance. The author in [29] developed a web-based human resource recruitment and management system. The system provided support for timely submission, collation, processing and dispensing of job applications. However, it lacks suitable platforms for planning and reports on wages and remunerations, training and development of HR.

While the authors in [30] proposed a performance appraisal system using multi-factorial evaluation model for eradicating cases of incorrect and subjective performance appraisal, the author in [31] presented a fuzzy data mining-based decision support system for monitoring and capturing the qualitative traits of personnel. The system is able to analyze real life situation but lacks the capacity to capture unstructured and quantitative information. In [26,32], RFID-based systems for monitoring employees at duty posts are proposed. The systems are geared towards increased productivity but suffer in the area of implementation which restricts the establishment of their versatility. An Indoor Real-time Localization System using passive RFID Tags and Artificial Neural Networks (ANN) is proposed in [33]. RFID technology was also used for accurate and speedy inventory and asset tracking. The system was not designed to run on networked and internet environments. In [34], an RFID-based Hajj pilgrim monitoring, tracking and identification system was designed. The system operates on offline mode and does not provide real-time information to its users. A system for monitoring student movement using active RFID is proposed in [35] as a solution to uncontrollable sequence of students' entrance to lecture halls and laboratories. The system is suitable for improvement on the attendance data management and reduction of administrative error and internal theft but failed to give consideration to personnel tracking. The authors in [4] presented a conceptual model for efficient personnel monitoring system. The model adapted and harnessed the versatility of RFID technology in supply chain management and agriculture to human resource management. The model was only tested on small local area network (LAN) environment while its performance on enterprise network or the internet remains unproven.

4 The Proposed System

The proposed online system for monitoring the activities of personnel in any public service is conceptualized in Fig. 2. The system combines the strengths of the existing and popular works proposed in [4,26,28,34]. It consists of subsystems for personnel records database, localization of the RFID readers and reference passive tags and the development of the middleware and the online aspect of the work. Personnel number, name, facial image, email address and assigned RFID tag number are stored in the database. The readers and reference tags are to be located in such a way as to reduce the noise level and interference. This unit generates and passes data to the RFID middleware, which is a JAVA-based engine. The engine receives and processes the raw data generated by the front-end using trained ANN and make a decision on the actual position of the subject at that instance. In order to make the system functional, RFID-enabled doors are used in restricted areas which place a level of control on where and when any employee can visit in the organization and enables the prediction of the location of an employee within the building at any instant.

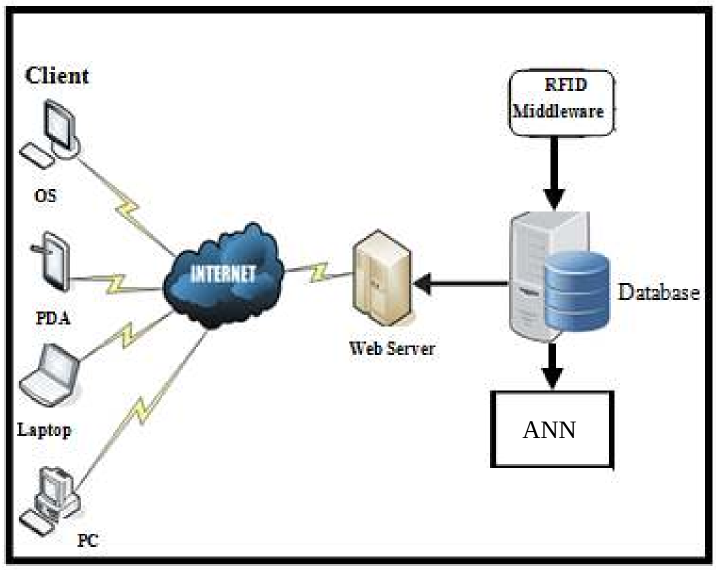

Fig. 2. Architecture of the proposed personnel monitoring system

4.1 Localization of RFID readers

Correct placement of readers is very important for the effectiveness of the system. The whole localization process is divided into two phases; signal measurement and position calculation. Indoor localization system determines the position of the subject in a physical space on continuous and real-time mode [36]. For obtaining the physical position of the subject in indoor environments, some position-related signal parameters corresponding to wireless communications between the target and the sensor were measured and the physical position of the target based on the signal parameters was calculated based on the illustration in Fig. 3.

In the first phase, some signals are transmitted between the target node (representing the communication entity attached to the personnel) and a number of reference (sensor) nodes. During this process, some properties of these signals, such as arrival time, signal strength, and direction, are captured by the receivers. As such, certain signal parameters, such as Time of Arrival (TOA) and Received Signal Strength Indicator (RSSI) are extracted. In the second phase, the physical position of the target node is determined based on the signal parameters obtained in the first phase. The determination is based on ranging, whereby distance or angle approximations are obtained based on trilateration and triangulation geometric approaches. Optimization-based statistical techniques were used to filter measurement noise and improve the accuracy of the result.

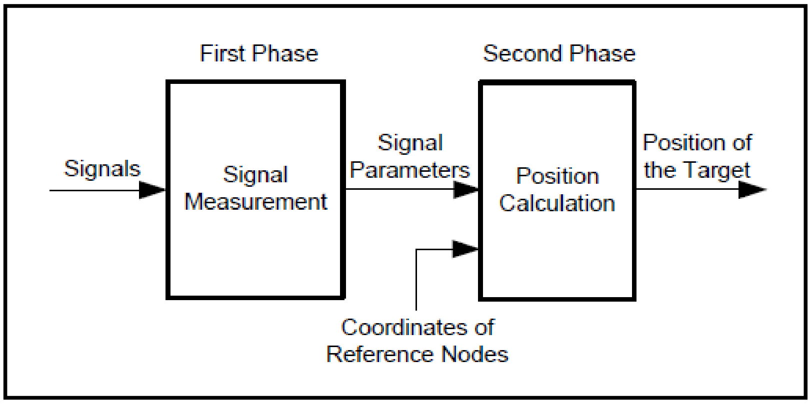

Fig. 3. The two phases in localization

4.2 Signal measurement

Time and received signal based methods of measurements were integrated to facilitate the elimination of the limitation suffered by either of them. The distance between the transmitting and the receiving nodes is computed from:

$$d = t \times s \tag{1}$$

t is the amount of time spent by the signal travelling from the transmitting to the receiving node, s is the traveling speed of the signal and d is the distance between the transmitting and the receiving nodes. If s as a known constant (based on a direct line of sight (LOS) between the reader and the unknown tag), then d is computed based on time observation. Due to the presence of several obstacles (furniture, walls, human beings and metallic objects) and interference of radio signals in the workplace, d is combined with results from RSSI-based technique. Based on the transmission power of the RF signal and path loss or the calibration model, the RSSI is translated into distance from the reader antenna and the RSSI transmission power for the unknown tag is mathematically expressed as follows [37]:

$$p(R) = p(L) - 10n\log(\frac{R}{L}) - B \tag{2}$$

$$B = \begin{cases} q \times p & if \quad (q < C) \\ C \times p & otherwise \end{cases} \tag{3}$$

n indicates the rate at which the path loss increases with distance (the attenuation factor), $p(L)$ is the signal power at the reference distance L, R denotes the distance between the transmitter and the receiver for the unknown tag, q is the number of obstacles between the transmitter and the receiver, p is the attenuation factor of the wall, C is the maximum number of obstacles between the transmitter and the receiver up to which the attenuation factor makes a difference. The signal strength in RSSI is converted to distance based on the Euclidean equation:

$$E_{i,r} = \sqrt{\sum_{i=1}^{N} (\theta_r - S_i)^2} \tag{4}$$

$E_{i,r}$ represents the relative position of the reference tag *r* and unknown tag *i*. Supposedly, the nearer reference tag gives smaller Euclidean distance compared to a farther reference tag. θ_r is the signal strength of the reference tag and S_i is the signal strength of the unknown tag received on the reader, N is the number of times the measurement is taken. The physical position (coordinate location) of the target is calculated based on the trilateration technique which uses three fixed non-collinear reference nodes to calculate the coordinate in 2D as shown in Fig. 4.

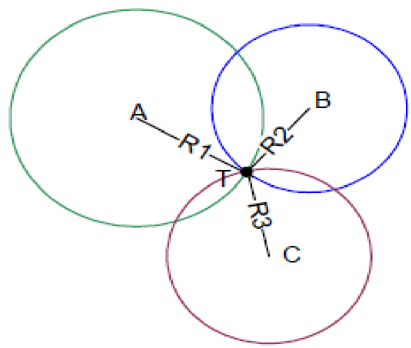

Fig. 4. Trilateration method

The trilateration equations for the calculation of the distance of the unknown tag from each of the reference positions $A(u_1, v_1)$, $B(u_2, v_2)$ and $C(u_3, v_3)$ are presented as follows:

$$x^2 + y^2 = r_1^2 \tag{5}$$

$$(x - u_2)^2 + y^2 = r_2^2 \tag{6}$$

$$(x - u_3)^2 + (y - v_3)^2 = r_3^2 \tag{7}$$

r_1, r_2 and r_3 are the distances of the unknown tag from the reference positions $A(u_1, v_1)$, $B(u_2, v_2)$ and $C(u_3, v_3)$ respectively. The estimated position of the personnel at any instant is obtained as the coordinates (x, y), which is calculated as follows:

$$x = \frac{r_1^2 - r_2^2 + (u_2 - u_1)^2}{2(u_2 - u_1)} \tag{8}$$

$$y = \frac{r_1^2 - r_3^2 + (v_3 - v_1)^2}{2(v_3 - v_1)} \tag{9}$$

For accurate results, the outputs are optimized using Back Propagation Network (BPN) which is an artificial neural network (ANN) technique. The reference data obtained by measuring the power levels of the reader antennas is fed to the network as training data. Once the network has been optimally trained, it is presented with the data for the unknown tag for location prediction.

4.3 Middleware design

The middleware translates the raw data generated by the reader into meaningful data that is passed to the database and it is designed using the SUN RFID middleware architecture. It is the interface that sits between the RFID hardware and applications. The RFID middleware (shown in Fig. 5) is majorly composed of the reader interface, data processor and storage, application interface and middleware management. Sun Java System RFID software is a critical RFID infrastructure component that allows a safe, secure and efficient data and device integration from the edge of an enterprise into its application systems. It has a dynamic and service provisioning architecture that enables scaling from small pilots to large deployments with high data volume [38]. The Java System RFID Software supports a variety of new and existing standards, such as EPC, ISO, Gen 2, passive and active tags and devices, read/write tags and commercial and government standards. It is a part of the Java Enterprise System (JES) and has the RFID Event Manager, the RFID Management Console, the RFID Information Server, and a Software Development Kit (SDK).

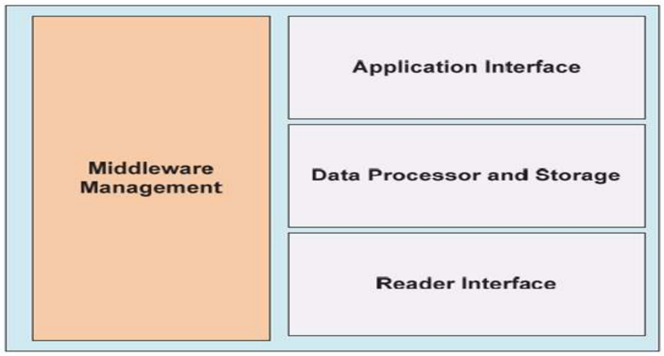

Fig. 5. RFID middleware

The RFID Event Manager is an event management system that facilitates the capturing, filtering and eventual storage of events generated by RFID readers. The RFID Management Console provides a browser based management interface, which allows configuration of various attributes and parameters of the middleware while the RFID Information Server stores and queries the EPC related data and manages inter-enterprise handling of the data. The SDK provides a development platform for building customized applications.

5 Experimental Studies

The implementation of the system requires an initial site survey and collection of data with tagged and referenced objects located in various rooms. The collected data consists of a relative signal strength value from each of the four antennas and the *x, y* coordinates of the measured locations within the rooms where the tags were located. Collected data were subsequently partitioned into training, cross-validation and testing subsets for the creation of an artificial neural network. Absorption and reflection induced interferences from walls, human and metallic sources were introduced to the system, resulting in four arrangements and ultimately, a localization algorithm is extracted from the network weights in order to give an accurate x-y prediction of the location of the object for the various arrangements. The proposed system uses four Alien 8800 865-867 MHz RFID reader, eight circular Alien antennas, and twenty four Alien squiggle tag (shown in Fig. 6), which is a Class 1, Generation 2 tag. Alien Omni Squiggle passive tags (shown in Fig. 7) were used and each operated within 860 – 960 MHz frequency range.

Fig. 6. Alien 8800 reader

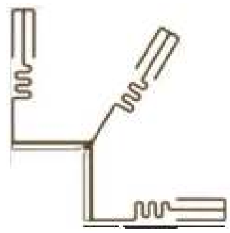

Fig. 7. Alien Omni squiggle tag

The implementation was carried out in an environment characterized by Rifidi Edge Software 1.3, Microsoft Window 7, PHP 6 and MySQL 5 on a Dell Inspiron Duo Core 3GB RAM laptop. A PC running JAVA programs was connected to the Alien readers through the LAN port. Rifidi was developed by Transcend Corporation to serve as middleware and development platform for RFID applications in various business and enterprise solutions. PHP is a server-side scripting language designed for web development and as a general-purpose programming language. MySQL 5 is an open Source SQL database management system developed, distributed, and supported by Oracle Corporation.

5.1 Experimental setup

The experiments were performed in an office complex with four distinct divisions; namely Director's office, Network Operation Centre, Software Development and Data Preparation. Each division is equipped with RFID reader with unique identification (ID). The technical specifications for the reader and the passive tags are presented in Tables 1 and 2 respectively.

Table 1. Specifications of alien ALR-8800 RFID

Specifications	Details
Supported RFID tag protocols	EPC Class 1 Gen 2, ISO – 18000-6c
Communications	RS232, LAN TCPI/IP(RJ-45)
Network protocols	DHCP, TCP/IP, SNTP, DNS, SNMP
Frequency	865.6 Mhz – 867.6 Mhz
Channels	10
Channel spacing	200 KHz
RF power	2 watts ERP
Antennas	4 ports for 4 read points, multi-static topology, circular or linear polarization, reverse polarity TNC connectors
Software SDK	Java and .NET APIs
Compliance safety	EN60950, EN 50364

Table 2. Technical specifications of alien squiggle passive tag

Specifications	Details
Operating frequency	860 – 960 Mhz
Operating mode	Passive, beam powered
Memory	240 bits NVM
Minimum programming cycles	10,000 write/read cycles
Operating temperature	-25°C to + 65°C
Recommended bending radius	70 mm
Thickness	0.42 mm
Dimensions	76.2 mm X 76.2 mm

5.2 System implementation

The application is web-based and designed to preregisters all the personnel to be monitored into the system's database which may be queried for a display of the list of all registered personnel with their arrival and departure times for specific days. On daily basis, the system keeps track of the entry and exit times and also records and stores the time and duration of each employee's visits to other offices, making it suitable for use in the access monitoring of sensitive areas such as the Network Control and equipment centers. As a measure against deceitful usage of the tag (such as possibility of leaving the RFID-tagged ID card in the office to give false impression of presence), an RFID-lock-based sensor was placed at the entrance to the building to read the pre-registered ID card of every employee before he/she is allowed to take his final or temporary exit. A case study of ten randomly selected personnel of the Information and Communication Technology Application Centre (ICTAC), Adekunle Ajasin University, Akungba-Akoko, Nigeria was carried out. The distribution of the selected staff and the strength of their departments (divisions) are presented in Table 3.

Table 3. Staff strength of ICTAC

Department	Staff strength	Selected personnel
Director	4	2
Network unit	5	3
Software development	6	3
Data preparation	4	2

Each of the selected personnel received an RFID-enabled Identity card, which he or she was mandated to wear. A database of name, designation, office number, facial image and other relevant data obtained from each of the selected personnel was created. The facial images were captured with 14.2 Megapixels Samsung ST65 Digital Camera. The real time data is filtered from the pool of data generated by the RFID reader and the chart of the total time spent in the office for the period of April 01-April 30 by the selected staff is presented in Fig. 8. 'A' represents the total working hours the employee spent in his/her own office, 'B' represents the total hours each employee spent in other places within the Centre, 'C' is the total hours each employee spent outside the Centre, 'D' is the number of days each employee arrived on or before 8.00 am while 'E' is the number of days each employee finally leaves the office on or before 04.00 pm. It is revealed that employee with tag number 'aauaict006' spent the highest number of hours in his office (157.77 hours) and also left his office the least time before 4pm throughout the period under review. The summary of the availability of the selected employee for the period under review is presented in Table 4.

Table 4 reveals that selected employee with ID "aauaict006" spent the highest percentage of time in the Centre while employee with ID "aauaict009" spent the greatest percentage of time outside the center for the period of the case study. Table 5 presents obtained data from the monitoring exercise (tracking) of the selected employees at different times of the day. The exercises were conducted five (5) times daily for 22 working days of the period to give a total of 110 records.

Table 4. Percentage of availability

Staff ID	Percentage of time within centre	Percentage of time outside centre
aauaict001	65.84	34.16
aauaict002	75.86	24.14
aauaict003	46.74	53.26
aauaict004	90.05	09.95
aauaict005	91.66	08.34
aauaict006	92.65	07.35
aauaict007	82.06	17.94
aauaict008	86.93	13.07
aauaict009	46.70	53.30
aauaict010	54.36	45.64

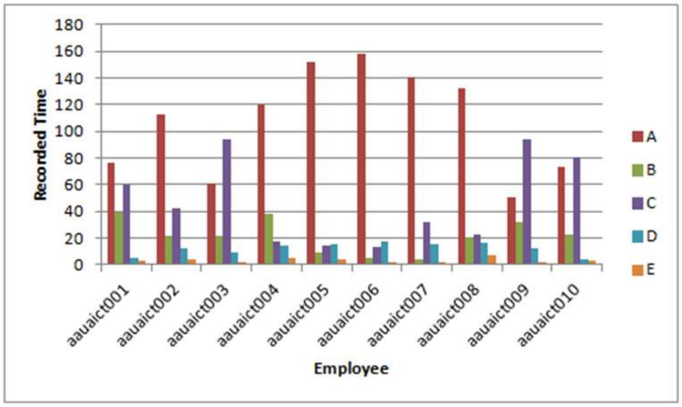

Fig. 8. Recorded times for selected employees

Table 5. Track records

Staff ID	Number of times found within his office	Number of times found in other offices	Number of times out-of-reach
aauaict001	63	34	13
aauaict002	71	25	14
aauaict003	37	41	32
aauaict004	75	22	13
aauaict005	72	24	14
aauaict006	85	17	8
aauaict007	68	35	7
aauaict008	65	29	16
aauaict009	45	32	33
aauaict010	40	49	21

It is deduced from Table 5 that selected employee with ID ‘aauaict006 stayed more at his duty post (office) than any other employee, employee with ID ‘aauaict010’ spent the least number of times in office while employee with ID ‘aauaict009’ spent more number of times outside ICTAC than any other employee.

5.3 Comparative analysis with other research studies

Several of the existing positions tracking systems use kth Nearest Neighbour and Linear Regression as their operational platforms while their performances are evaluated based on the obtained Mean Estimated Error (MEE), Standard Deviation (SD) and Percentiles values. Table 6 presents the obtained values for selected parameters by the proposed techniques and the kth Nearest Neighbour (NN) and Linear Regression(LR) techniques from [28,33] respectively. The results in Table 6 reveal that that the new technique outperforms the Nearest Neighbor and Linear Regression-based techniques for all the parameters.

Table 6. Comparison of the performance evaluation of ANN, kthNN and LR

Parameter	Artificial neural network (current work)		Kth nearest neighbour [28]		Linear regression [33]	
	Without obstacles	With obstacles	Without obstacles	With obstacles	Without obstacles	With obstacles
Mean estimated error	0.422 m	0.5795 m	0.4914 m	0.61 m	0.4933 m	0.605 m
Standard deviation	0.2369 m	0.3675 m	0.2575 m	0.3955 m	0.3213 m	0.4035 m
50th percentile	0.3980 m	0.4195 m	0.4201 m	0.4289 m	0.4144 m	0.4377 m
75th percentile	0.59 m	0.7606 m	0.6249 m	0.8 m	0.6276 m	0.7810 m

6 Conclusion

The development of an online system for the monitoring (tracking) of personnel arrival and exit times as well as movement has been presented. The research addressed time and availability as major issues in the measurement of the effectiveness of employees in their workplace. The data generated from the system revealed that it can be integrated with existing payroll system and other human resource information systems (HRIS) of any organization to give accurate data in respect of employee's availability on duty post and other management decision making processes. The new system is equipped with facilities for online tracking, detailed movement statistics and passive RFID technology which ensure its relative advantage over similar systems through its simple, less bulky and power efficient capabilities. In view of the fact that some jobs require regular movement of personnel, future research therefore focuses on the development of a new technique for tracking of personnel whose duties cut across offices or buildings. Consideration will also be given to the integration of GPS, RFID and WLAN technologies to achieve greater purpose for outdoor and long distance monitoring.

Competing Interests

Authors have declared that no competing interests exist.

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