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Using IoT technology for computer-integrated manufacturing systems in the semiconductor industry☆

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ABSTRACT

The evolution of semiconductor manufacturing between lot and equipment has an increasingly complex relationship in the track-in/track-out process mechanism. Failure of reading or updating barcodes may cause some lots to scrap with mis-operation. In this paper, it proposed an Internet of Things (IoT) based Computer-Integrated Manufacturing (CIM) system used in Feature Advantage Benefit (FAB), that semiconductor company used Radio Frequency Identification (RFID) into 300-mm (FAB), and according to the information provided by the semiconductor company MTB (Manufacturing Technical Board). This solution to change the operation process flow to fit the CIM system characteristics of Fab in Manufacturing Execution System (MES). It also use IoT design strategy and the system architecture of this new IoT solution. The result of this research is to incorporate deep learning method in the IoT system into the current CIM system to reveal the benefits in FAB. It estimate to save about US$ 2.8M by adopting IoT RFID instead of tagging to identify a work in process lot in the initiation phase. The company can gain greater asset visibility, reduce the costs of man-power requirements and connect with the worldwide trend.

1. Introduction

With the advent of the fourth industrial revolution (Industry 4.0) manufacturing systems are transformed into Semiconductor Industry. In this transformation, the Internet of Things (IoT) and other emerging technologies pose a major role. To shift manufacturing companies in computer-integrated manufacturing (CIM). The so-called smart parts-based manufacturing system addresses these concerns well. The smart part carries operating instructions for the manufacturing worker or machine. Uniquely identified individual parts can process according to their specific requirements based on individual customer preferences. Therefore, it is necessary that each part correct identified, to ensure reliable process control in such a flexible and customer-oriented manufacturing system.

When a new component released, systems always require fine tune. Therefore, it must have a gap between new RFID system and old SMART system. Although it has an experienced EA term, there still exist challenges for system stability, and it will trace it by on-call rate until it is the same level as other FAB.

Many companies use RFID to trace their products. Until now, RFID tracking has only been able to locate a tag's position to within a rough area (about 13*13 mm). The second challenge is thus to improve the precise position location of RFID tags. The new technology of PDA and wireless may change dispatching behavior such that all CIM systems need to consider in order to gain system enhancement [1].

Focusing on FAB, the biggest challenge currently faced is the maturation of the integration between the RFID reader and the equipment controller. Since the CIM host does not connect to the RFID reader directly, the only way it can get the information stored in the RFID Tag is through the equipment controller. If the equipment controller does not send the correct information from the RFID Tag, it will be very difficult to determine problems when they arise, because there are too many factors that may impact the RFID reading result [2].

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In this paper, it will describe how to use radio frequency identification (RFID) in computer-integrated manufacturing (CIM) as a lot identification system with the following benefits:

- Low cost when compared with smart tag systems
- No need to detach tag while POD is cleaned
- Increased ease of carrier tracing
- Reduces the probability of missing lots (when compared with smart tag systems)
- Ease of maintaining the system & minimizing tag failure rate
- Reduced complexity of CIM system
- Operation Benefit with Smart Tag
- Ability to fulfill a "place and go" scenario
- RFID is easier to operate split function when compared with barcodes [3,4].

The purpose of test lot use to analysis and simulate the process result of the equipment. In FAB, the smart tag used to carry several pieces of test lot information; the equipment can directly get detailed secure information from the tag, such as lot stage and recipe. The user can update test lot information to the tag from the operation management interface (OMI). While front opening unified pods (FOUPs) are loaded onto the equipment load port, a tool control system (TCS) reads the test lot information from the tag [1,5,6]. If the test lot data exist in the tag, the TCS will process this lot.

In FAB, RFID acts as an alternative lot identification method for a 300-mm environment. All lot data need to be stored with RFID for TCS inquiry. With a smart tag system, however, the RFID treated differently. Limitations on storage capacity mean that date storage is limited. In other words, RFID cannot successfully store all the test lot information. As a result, other solutions must find in order to store the data [4]. In order to implement the test lot, a channel is necessary between the RFID and the equipment to enable the smart tag to provide the same function as FAB. This paper to propose a solution to change the operation flow to fit the characteristics of IoT. In addition to introducing the design concept and the system architecture of this new IoT solution, the objective of this paper is to incorporate deep learning in the IoT system into the current CIM and to reveal the benefits in FAB [7,8].

The rest of this paper was organized as follows. Some background information was introduced in Section 2, including RFID technology and design strategy. In Section 3 describes IoT based CIM system design for open Cassette, includes design purpose, system architecture and detail process flow. The IoT based CIM system design in 300-mm FAB, is further revealed the separate FAB, separate wired link and foup tray in Section 4. A series of performance evaluation and relation analysis are carried out in Section 5. Finally, it concludes this paper and give some future research work in Section 6.

2. Related work

2.1. RFID technology

RFID has become a well-known technology in recent years. It has applications in many fields, including ecology, supermarkets, banks, security, and communications, among others [2,9,10].

The structure of an RFID system is show in Fig. 2. The RFID system consists of three basic components: a reader/programmer, an antenna and a tag or transponder. The antenna sends an electrical wave as a trigger and a radio frequency (RF) tag converts the electrical wave to electrical flow via a coil. Then the RF tag sends another electrical wave as information to the reader [2,5,6]. The tag operation flow shown in Fig. 1.

Before using RFID technology as solution, the features of RFID must consider [11–14]:

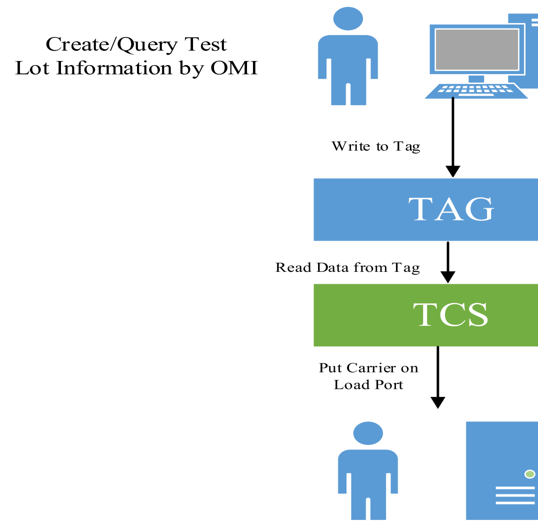

Fig. 1. IoT tag operation flow.

(1) Operating Distance:
"proximity" (below 100 mm) → "medium range" (below 400 mm) → "vicinity" (long range — 1.5 m) → "far field" (0.5 to 12 m — 2450 MHz, passive power) → Up to 30 m (active power tags depending on microwave frequency)
(2) Tag Characteristics

- Memory: (ROM); (WORM); (EPROM or EEPROM). 1 bit to several Mbytes.
- Physical Form: Tags are not limited by form, shape or the nature of a protective housing.
- Cost: Prices have dropped to a low range of 1 to 10 cents, though active and long-range tags are still expensive. With increasing use, production costs and hence prices will drop.

(3) Miniaturization: In Japan, an ultra-small (0.4 × 0.4 = 0.16 mm^2) RFID chip has been developed named the "mu-chip".
(4) Limitation & Cautionary Notes [15,16]:

- 13.56 MHz waves are not absorbed by human tissue or water, permitting operation through water and through human barriers.
- 2450 MHz UHF waves must use with caution where human contact is involved. These signals easily penetrate wood, paper, board, clothing, paint, dirt etc.
- Short wavelengths of radipendently without human intervention in confined operating areas.

The basic components of a generic RFID system are a transponder (RFID tag), an antenna, and a transceiver/reader as Fig. 3. [17–19]:

(1) Transponder/tag: The word transponder, derived from transmitter/responder, reveals the function of the device. An RFID tag is simply a microchip that wirelessly transmits information that encoded in the chip. The information carried via a radio frequency in the specific bandwidth to an RFID transceiver, typically over short distances.
(2) Antenna: Each RFID system includes at least one antenna to transmit and receive the RF signals.
(3) Transceiver/reader: The RF transceiver is the source of the RF energy used to activate and power the RFID tags. It receives the encoded signal from the tag, decodes the tag's

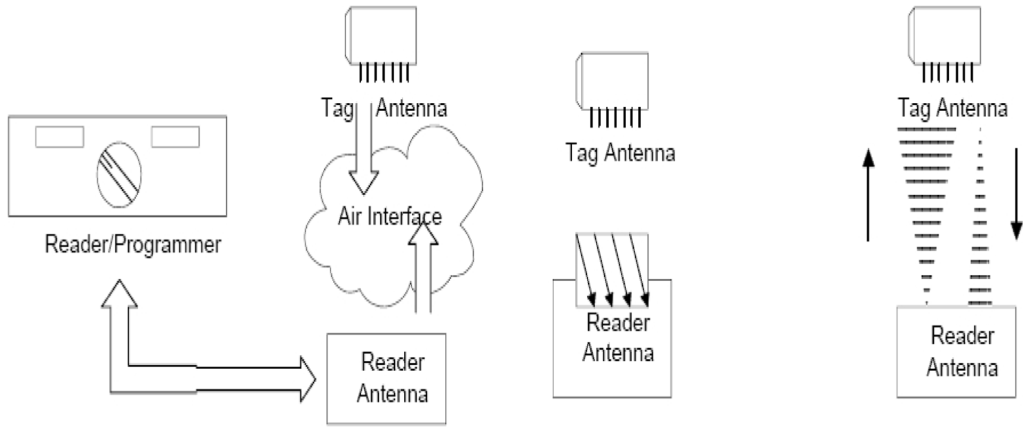

Fig. 2. RFID system structure and inductive/propagation coupling.

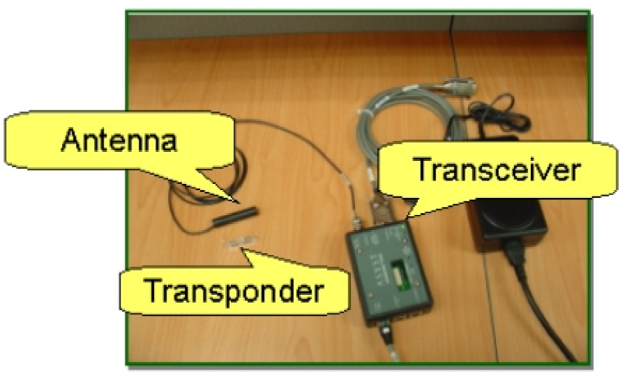

Fig. 3. The basic components of a generic RFID system.

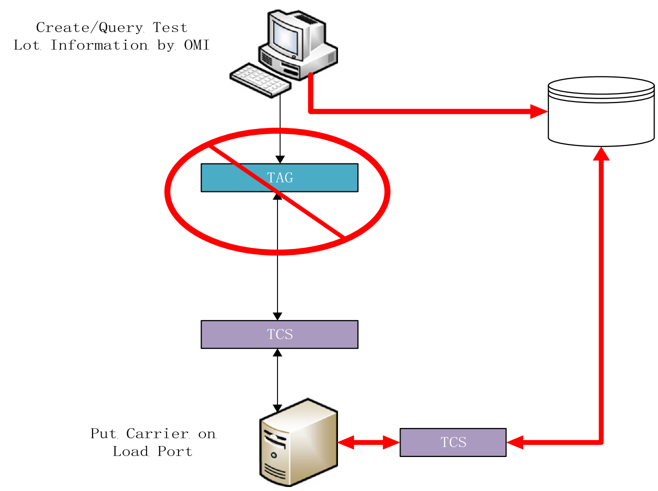

Fig. 4. New RFID operation flow in FAB.

identification, and then transmits the identification with any other data from the tag to the host computer [20,21].

Communication between RFID tags and a reader is wireless. When an RFID transceiver and an RFID tag are close together, the tag transmits a radio frequency signal that can be captured by the antenna. The transceiver's application system can detect duplicated transmissions and filter them out when communicating to the host system [22–24].

2.2. Design strategy

Almost all FAB10 equipment are old from FAB7 and it should verify the old CIM design architecture. It decide to change the input of lot identification only, and there is no connection between equipment and RFID system [25,26]. It desire that FAB IOT based CIM will stay similar to the old architecture of FAB-CIM. In addition, it verify all operation scenarios with each equipment type (total 50 types) to make sure it is smoothly and security in operation [27–29].

However, in the FAB of the IOT based CIM solution as Fig. 4, the RFID tag is used to replace the smart tag. In order to reserve the capacity of the RFID, the traditional operation flow in the tag environment has to change for storing test lot information. First, in order to integrate other functions in the SiView system, the new interface has to be designed based on the OMI, which is used to create and maintain test lot data by the user [30–32]. Second, it need to create tables (CSFRRFID_DATA, CSDRRIDDATA_PARA) on the MES database to store the test lot information [33–35]. The most important thing is that the key transaction between OMI to MES DB and MES DB to TCS needs to be set up. As shown in Fig. 4, if the users add test lot data from OMI, that information would be kept in the MES database, not RFID. Moreover, when the FOUP of the test lot is loaded onto the port, TCS would send a request to the MES DB to get test lot information [36,37].

2.3. Smart system

The objective setting smart system process is a difficult one for most individuals, particularly those who have never been asked to set objectives. The process can be as simple as sitting down with the company objectives and ask the question, "How can I best help to meet company objectives?" From that answer comes to set the individual people objective. If the company's objective is to improve the customer satisfaction score, the team can work on providing more self-service information to reduce the number of calls and call wait-time or offer tools to improve customer service levels by clarifying how to communicate with a customer [38–40].

The S.M.A.R.T. method is one way to help you remember how to walk through the smart system process to set your objectives.

- S — Specific: There are several key factors which should be present in the objectives that are set for them to be effective. They should be specific. They should describe specifically the desired result. Instead of "better customer service" the objective should be "improve the customer service using the customer service survey".

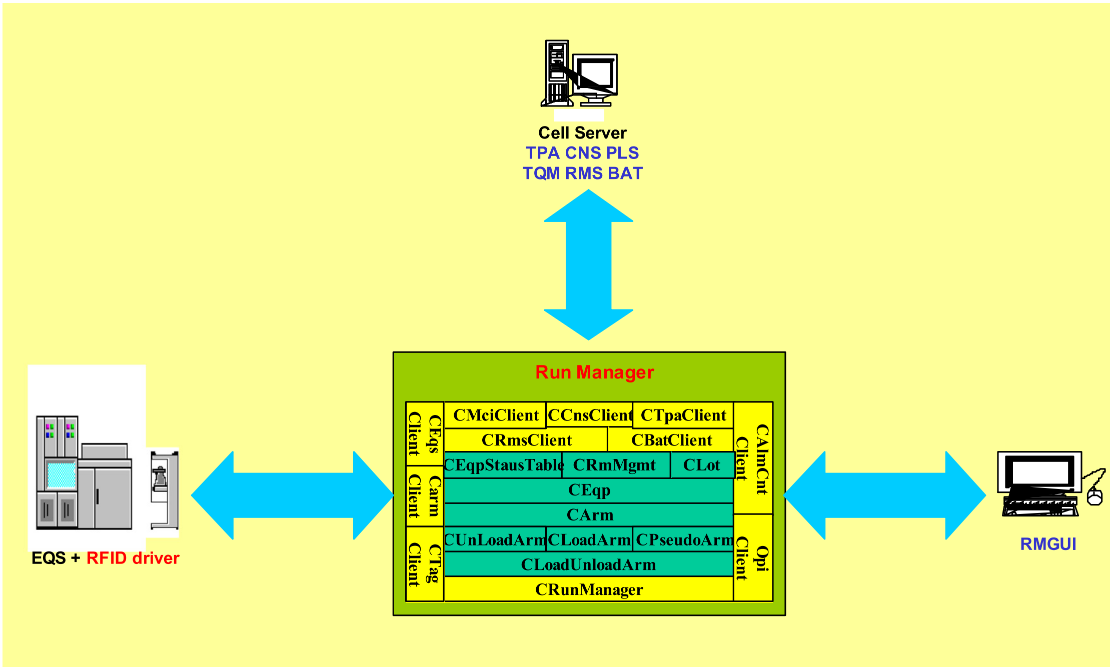

Fig. 5. RM high level design architecture.

Table 1
The detailed flow of how TE executes operation in the AUTO mode.

No.	From	To	Description	Remark
1	RMGUI	RM	TE sets batch size for this run. This batch size can lead RM to auto-start-process.	Optional. This batch size is only for batch equipment.
2	RFID driver	RM	TE puts lot on load port and confirms button to send AskTrackIn for loading lot.	The RFID type includes “LOT”, “EMP” and “TST”. Here, only “LOT” is acceptable
3	RM	Cell Server	Gets lot & run information, checks constraints and records position (PosChanged).	TQM is must for “PosChanged”.
4	RM	EQS	RM starts process if batch size is satisfied.	Optional.
5	EQS	RM	EQS sends to issue empty RFID on load port.	Optional. This is only for cassette-switch equipment. (Request Format is EMP + LOTID)
6	EQS	RM	EQS sends to issue RFID on unload-port.	Optional. This is only for cassette-switch equipment. (Request Format is LOT + LOTID)
7	EQS	RM	Process complete. EQS sends ReadyUnload to track-out lots.	Optional.
8	RM	Cell Server	Gets lot & run information, checks constraints and records position (PosChanged).	TQM is must for “posChanged”.
9	RFID driver	RM	TE presses unload-button to AskTrackOut for unloading lot.	Optional. This action is to open the door and unload lot. This is only for “INDOut” mode. (Format: ID is LOTID or null)

- M — Measurable: The second is much more specific and also addresses the second factor — measurable. To use the objectives as a part of a review process it should be very clear whether the person meet the objective or not.
- A — Achievable: The third is setting objectives that they be achievable. For instance, an objective for “100 percent customer satisfaction” is not realistically achievable. It is not possible to expect that everyone need 100 percent satisfied with their service. A goal of improvement in customer satisfaction is better. They are not likely to have enough influence over the customer interaction process to improve satisfaction.
- R — Realistic: Realistic objectives are objectives that recognize factors which cannot be controlled. Another way, realistic goals are potentially challenging but not so challenging that the chance of success is small. They can be accomplished with the tools that the person has at their disposal.
- T — Time-based: The final factor for a good objective is that it is time-based. Improve customer service is making the objective real and tangible. The implied date is the date of the next review, when the employee will be held accountable for the commitments that they have made through their objectives [41].

3. IoT based CIM system design for open cassette

An on-inertial particle swarm optimization with adaptive elite mutation algorithm for hyper-parameters of GPR, called NIPSO-GPR, is proposed. NIPSO-GPR consists of three parts: The first one is a uniform non-inertial velocity update (NIV-U) formula, which guides the flight direction of particles through making full use of

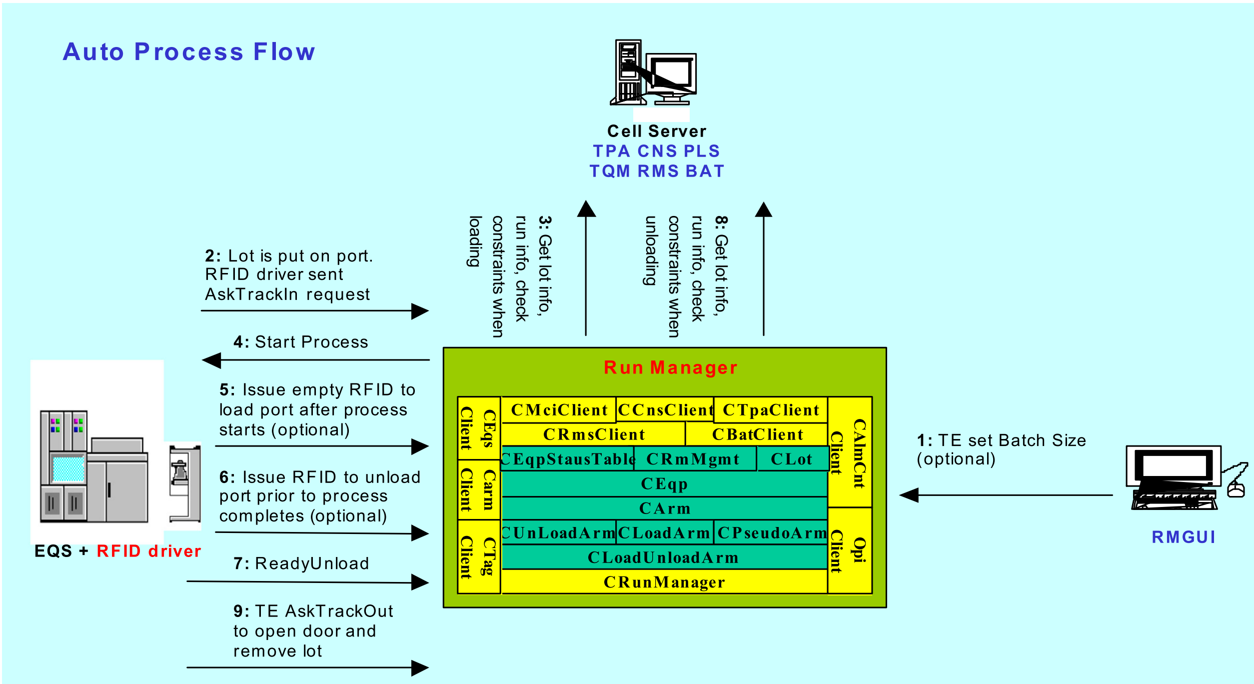

Fig. 6. RM-RFID auto process flow.

Table 2
The detailed flow of how TE executes operation in the MANUAL mode.

No.	From	To	Description	Remark
1	RFID driver	RM	TE puts lot on load port and confirms button to send AskTrackIn for loading lot.	Only "LOT" is acceptable
2	RM	Cell Server	Gets lot & run information, checks constraints and records position.	TQM is must for "posChanged".
3	TE	EQP	TE chooses recipe and starts running.	
4	EQS	RM	EQS sends to issue empty RFID on load port.	Only for cassette-switch equipment. (Request Format is EMP + LOTID)
5	EQS	RM	EQS sends to issue RFID on unload-port.	Only for cassette-switch equipment. (Request Format is LOT + LOTID)
6	RFID driver	RM	TE presses unload-button to AskTrackOut for unloading lot.	Open the door and unload lot. This is only for "INDOut" mode.
7	RM	Cell Server	Gets lot & run information, checks constraints and records position.	TQM is must for "PosChanged".

swarm environment information to increase the global searching ability of particles. The second one is an adaptive elite mutation strategy, which helps particles search for a local optimum to select optimal hyper-parameters of GPR on the condition of no prior knowledge [42–44].

● Design purpose
The Fab IoT based CIM is to integrate the RFID technology into open cassette environment:

1. To provide a more efficient and effective equipment lot tracking solution instead of barcode solutions in the open cassette environment [45,46]
2. To support the "place then go" scenario with a low cost instead of a SMIF environment

● Design scope
The Fab IoT based CIM design scope include as bellows:

1. Enable operation flow with RFID technology
2. Enable auto-issue RFID function. Hold lot to prevent MO if it fails.
3. Enable auto-start-process mechanism instead of confirm-start by TE
4. Enable TEST LOT operation flow
5. Miscellaneous: Post-Changed, Manual-issue RFID function in RMGUI, CMP Sorter function.

3.1. System structure and architecture

The system architecture describes the key application integrated to enable operation flow with RFID technology. The specific description shown in Fig. 5. This just include RFID function for RM Level Design Architecture.

- Run Manager: supervises and coordinates the lot operation.
- Cell Server: provides lot information, constraints, run information etc.
- EQS: controls the physical equipment.
- RFID driver: new component in this project, reads/writes the RFID.
- RMGUI: GUI for TE. TE executes issue-RFID manually and changes operation mode.

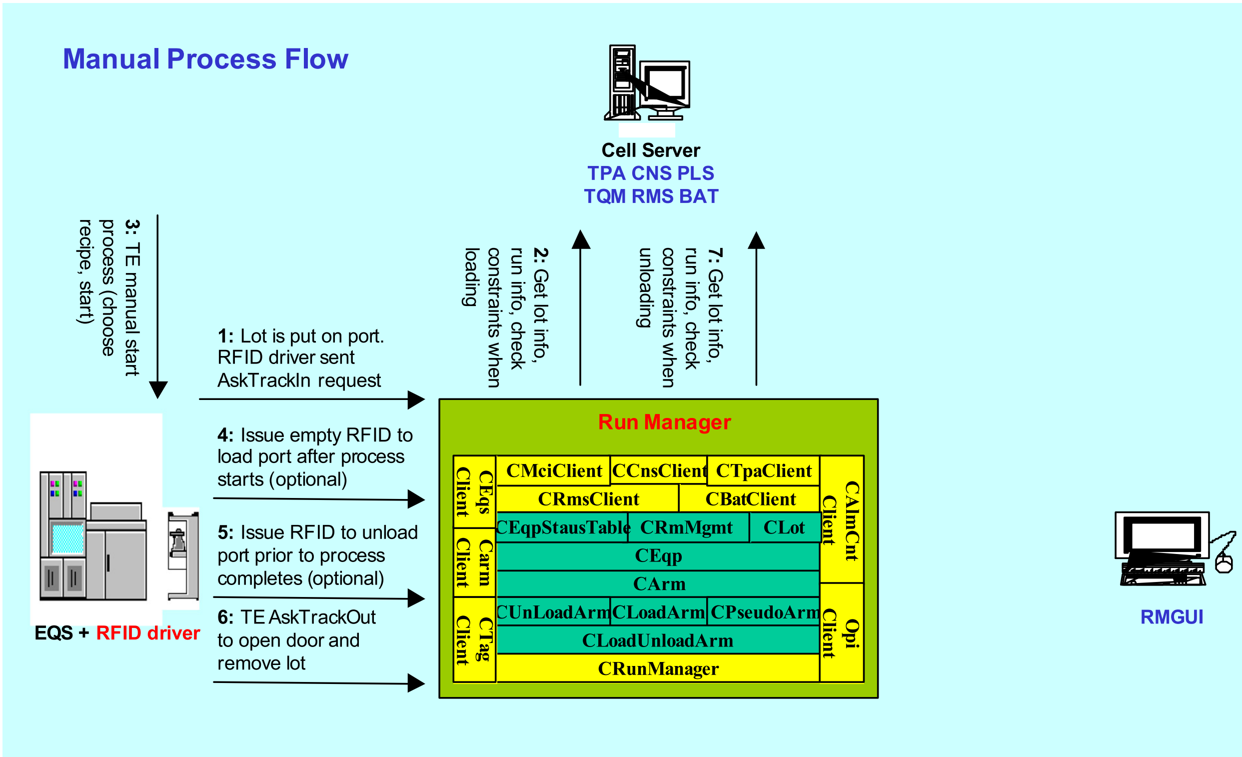

Fig. 7. RM-RFID manual process flow.

Table 3
The detailed flow of TE executes TEST LOT operation in the AUTO mode.

No.	From	To	Description	Remark
1	RMGUI	RM	TE sets batch size for this run. This batch size can lead RM to auto-start-process.	Optional. This batch size is only for batch equipment.
2	RFID driver	RM	TE puts lot on load port and confirms button to send AskTrackIn for loading lot.	Only “TST” is acceptable
3	RM	Cell Server	Gets run information and records position (PosChanged). Does not get lot info or track-in lot, does not check constraints or other related lot info.	TQM is must for “PosChanged”.
4	RM	EQS	RM starts process if batch size is satisfied.	
5	EQS	EQP	EQS chooses recipe and starts running.	
6	EQS	RM	EQS sends to issue empty RFID on load port.	Optional. This is only for cassette-switch equipment. (Request Format is EMP + LOTID)
7	EQS	RM	EQS sends to issue RFID on unload-port.	Optional. This is only for cassette-switch equipment. (Format is TST + LOTID)
8	EQS	RM	Process complete. EQS sends ReadyUnload to track-out lots.	
9	RM	Cell Server	Gets run information and records position (PosChanged). Does not get lot info or track-in lot, does not check constraints or other related lot info.	TQM is must for “posChanged”.
10	RFID driver	RM	TE presses unload-button to AskTrackOut for unloading lot.	Optional. This action is to open the door and unload lot. This is only for “INDOut” mode. (Format: ID is LOTID or null)

3.2. Detailed process flow

Here, the main process flow composes of auto-process-flow, manual-process-flow, test-lot-process-flow, and manual-issue-RFID by RMGUI.

● AUTO PROCESS FLOW

The TE executes operation in AUTO mode. The detailed process flow shown in Table 1 and Fig. 6. The RFID-based auto process flow can execute from step 1 to step 7 for FAB.

● MANUAL PROCESS FLOW

TE executes operation in MANUAL mode. The detailed flow shown in Table 2 and Fig. 7. This mode just for manual process flow, the performance is need to update.

● TEST LOT PROCESS FLOW

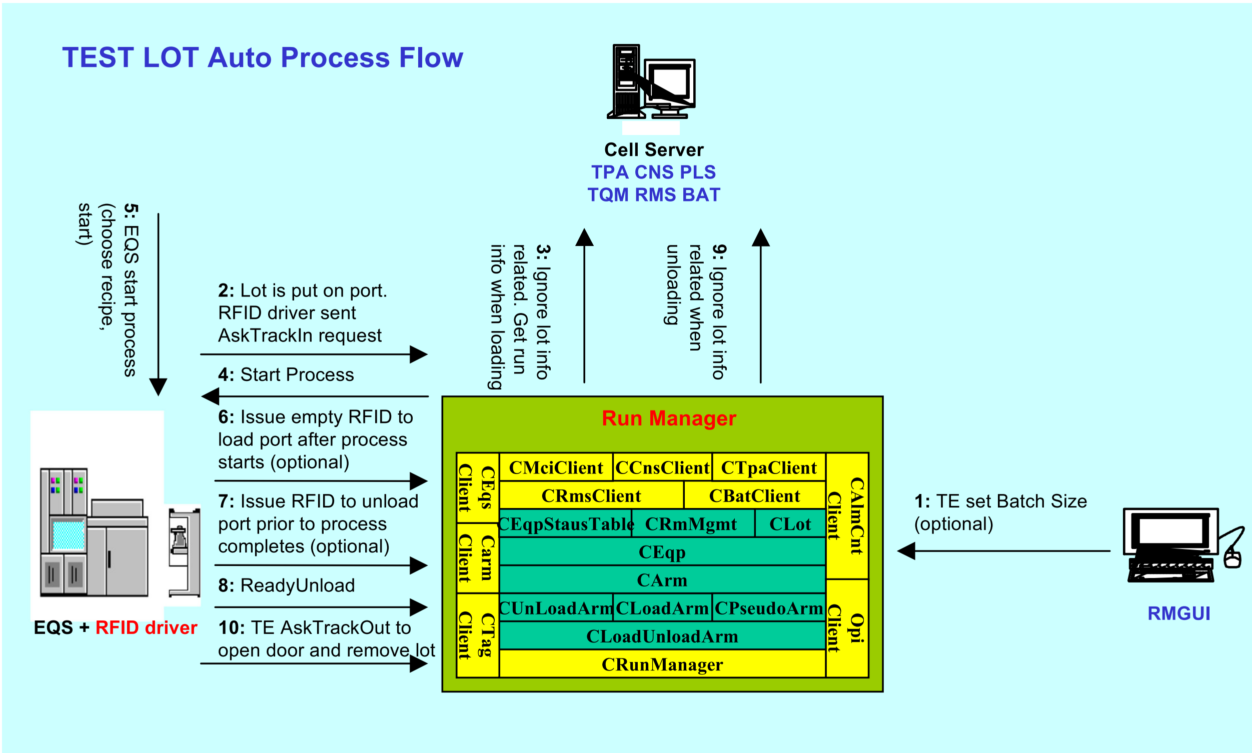

Fig. 8. RM-RFID test Lot auto process flow.

Table 4
The detailed flow of TE executes TEST LOT operation in the MANUAL mode.

No.	From	To	Description	Remark
1	RFID driver	RM	TE puts lot on load port and confirms button to send AskTrackIn for loading lot.	Only "TST" is acceptable
2	RM	Cell Server	Gets run information and records position (PosChanged). Does not get lot info or track-in lot, check constraints or other related lot info.	TQM is must for "PosChanged".
3	TE	EQP	TE chooses recipe and starts running.	
4	EQS	RM	EQS sends to issue empty RFID on load port.	Optional. This is only for cassette-switch equipment. (Format is EMP + LOTID)
5	EQS	RM	EQS sends to issue RFID on unload-port.	Optional. This is only for cassette-switch equipment. (Format is TST + LOTID)
6	RFID driver	RM	TE presses unload-button to AskTrackOut for unloading lot.	Optional. This action is to open the door and unload lot. This is only for "INDOut" mode. (Format: ID is LOTID)
7	RM	Cell Server	Does not get lot info or track-out lot, does not check constraints or other related lot info.	TQM is must for "PosChanged".

Table 5
The detailed flow of TE executes manual issue-RFID on RMGUI.

No.	From	To	Description	Remark
1	TE	EQP	TE puts lot on port but does not press confirm-button.	Lot is not loaded into equipment.
2	RMGUI	RM	TE manual issues RFID on RMGUI. II. RMGUI reads RFID information III. RMGUI gets lot information from PROMIS IV. TE issues RFID	RMGUI gets lot information from PROMIS and issues RFID according to TE request.
3	RM	RFID driver	RM receives issue-RFID request from RMGUI and sends issue-RFID to RFID driver immediately.	RM replies the result to RMGUI.

TE executes TEST LOT operation in AUTO or MANUAL mode. The detailed flow in AUTO mode shown in Table 3 and Fig. 8, and in MANUAL mode shown in Table 4 and Fig. 9. This performance shows RM-RFID Test Lot auto is better than Manual Process Flow.

● MANUAL ISSUE-RFID PROCESS FLOW

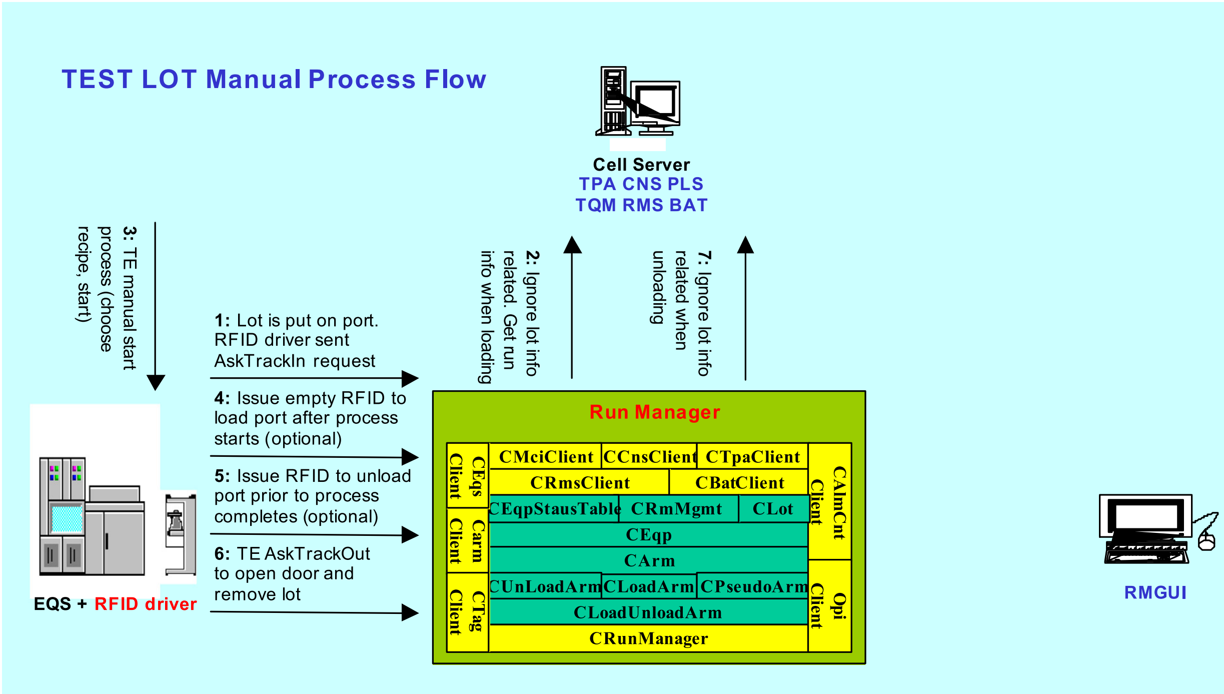

Fig. 9. RM-RFID test lot manual process flow.

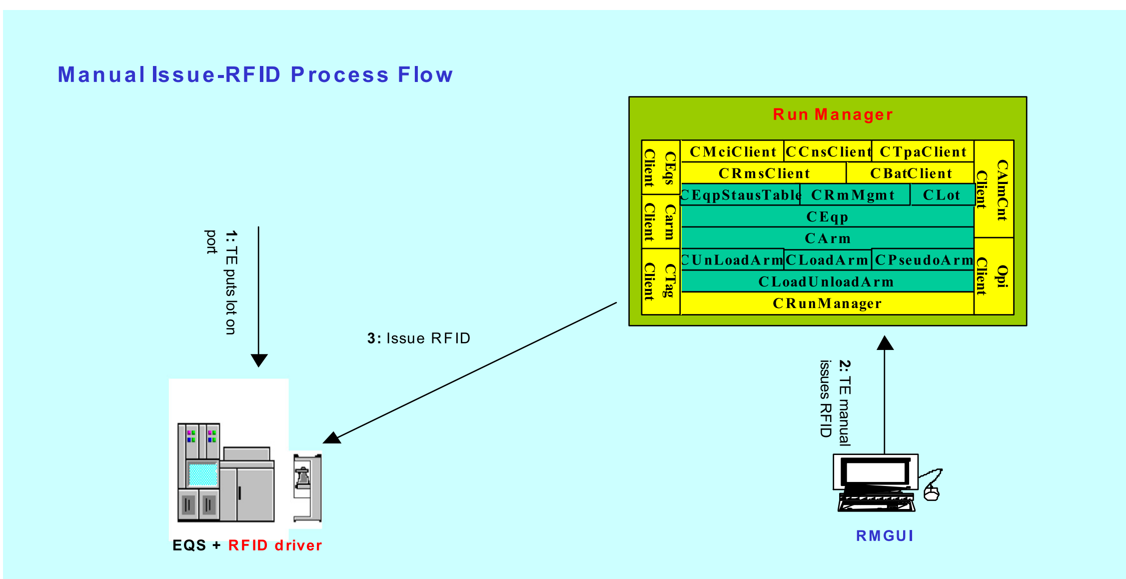

Fig. 10. RM manual issue RFID process flow.

TE executes manual issue-RFID on RMGUI. TE can use this function for

- Fixing the RFID if auto-issue fails in the operation.
- Changing the RFID to enable TEST LOT operation.
- Issuing empty RFID to avoid duplicate lots in Rack systems

The detailed flow shown in Table 5 and Fig. 10 show RM Manual Issue RFID Process Flow. This include RFID-base is more easy and quickly to complete run manager process flow.

4. IoT based CIM system design in 300-mm FAB

After reviewed the EA operation scenarios of all equipment types in production, the system architecture in this 300-mm IoT RFID solution can classified into three models: separate-wired link, single-wired link, and FOUP tray [1].

4.1. Separate-wired link

In this model, the CIM host system connects to the RFID reader and the equipment controller separately. This means that the CIM host has to communicate to the RFID reader and the equipment controller at same time. The specific description shown in Fig. 11.

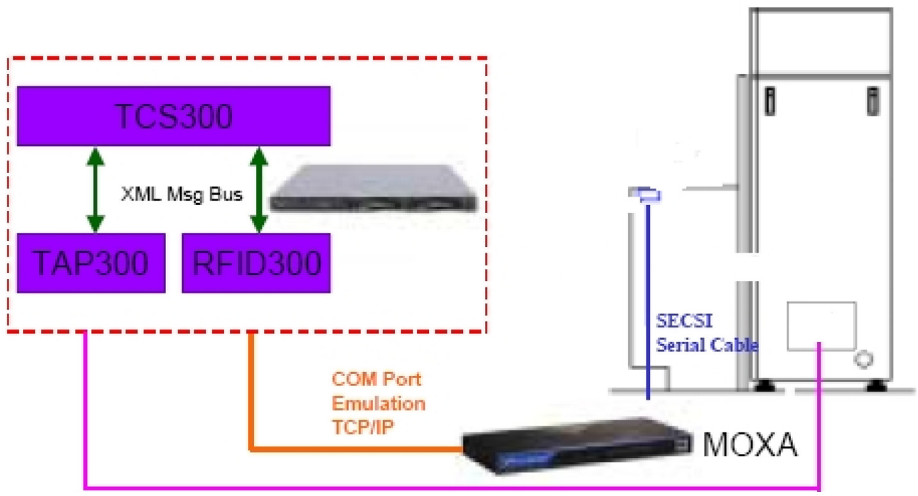

Fig. 11. Separated-wired link.

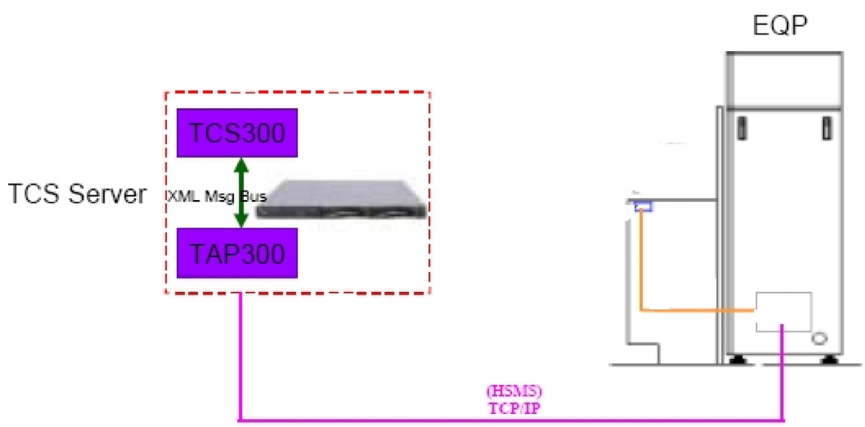

Fig. 12. Single-wired link.

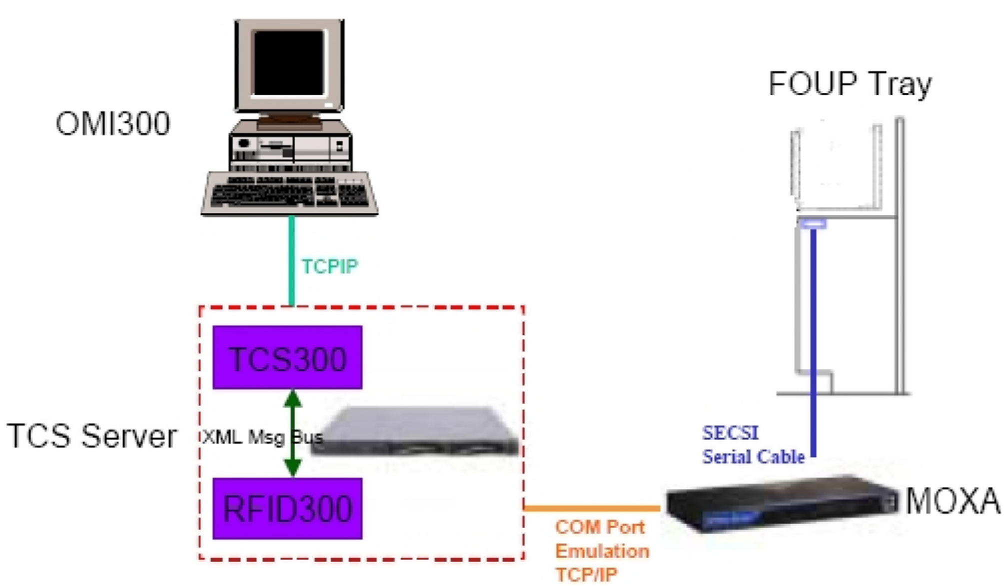

Fig. 13. Foup tray.

The advantage of this model is that the CIM host can talk to the RFID reader directly without passing through the equipment controller. This means that the accuracy of RFID reading will not affect by the status of the equipment controller, for example equipment alarms.

Table 6
Cost comparison between smart tag and RFID tag.

Initial Cost(US$) @ 30K Fab		Unit Price			Qty	Amount
Stmart Tag	Smart Tag	350			9,000	3,150K
	Battery	12			0	0
	Initial Cost					3,150K
RFID	RF Tag	7			9,000	63K
	(a)Handy Reader with MES Link	1,500			200	300K
	(b)Handy Reader without MES Link	380			200	76K
	Initial Cost					(a) 363K / (b) 139K
Initial Cost Saving						(a) 2.8M / (b) 3M
Sustain Cost Per Year(USD$)		Fix cost	Fix Rate*1	Initial Cost	Qty*2	Amout
Smart Tag	Smart Tag(10%)	50	90%	350	500	42.5K
	Battery	12	-	-	1,500	18K
	Sustain Cost					60.5K
RFID	(a)Handy Reader with MES Link	-	-	-	-	60K
	(b)Handy Reader without MES Link	-	-	-	-	15.2K
	Sustain Cost			(a) 60K /(b) 15.2K		
Sustain Cost Saving Per Year						(a) 0.5K /(b) 45.3K

Note: *1.base on Fab3 experience *2. base on Fab 12 experience

Table 7
Cost comparison between Barcode and RFID Tag.

People productivity	Save manpower of DL to manipulate barcodes in preparing, printing, attaching, exchanging, discarding, tracking and waiting for double check lots. Need no exchange between SMIF and non-SMIF environment.
Cost reduction/avoidance	Reduce M.O. cases which come from lot id v.s. cassette (in barcode) operation.

Table 8
Categories of FAB RFID 'read fail' events.

NO	Alarm category	Count	%	Sponsor
1	CID Not Found	470	35%	MITD,EE
2	Manual Run	278	20%	MFG
3	No ReadID Event	251	18%	MTD,EE
4	Tool Not Released	127	9%	MFG,EE
5	Eqp Alarm	89	7%	EE
6	Reader Problem	77	6%	EE
7	FOUP Tag Problem	68	5%	MFG
8	Others	4	0.3%	MTD

This model's disadvantage is that there are extra network cabling costs and maintenance works. In addition, the separate-wired link is not the trend for 300-mm solutions, so the semiconductor company has to pay more labor and retrofit fees to equipment vendors for hardware and software modifications. Currently the standard practice FAB in semiconductor companies is FAB phase I.

4.2. Single-wired link

In this model, the CIM host connects to the equipment controller only. The equipment controller has to take the responsibility to communicate with the RFID reader and pass the information to the CIM host. The specific description shown in Fig. 12.

This model is advantageous because besides the cost saving of network cabling, this is the standard for all 300-mm FAB systems around the world. The whole semiconductor industry, including IC makers and equipment makers, invested in making this model work better. In the event of any problem, a solution or a reference can easily find from other foundries' experience, and the bargaining power against equipment makers is much stronger.

The disadvantage of this model is that because the RFID reader is connected to the equipment controller, the CIM host may fail to get RFID information from the equipment controller if the equipment has an abnormal status, for example an alarm or without any reason. This will make problem determination very difficult, because the internal design of the equipment is unknown. Currently the standard practice FAB in semiconductor companies is — Fab phase 2/3.

4.3. Foup tray

The FOUP tray is the only device that can use to write the content of an RFID tag in the semiconductor company's 300-mm RFID solution. The structure of the FOUP tray is very simple as Fig. 13. An RFID reader connects to the CIM host directly.

Table 9
Fab-RFID project benefit.

Project Name:RFID Project												
Return driver	Business assumption	Estimated benefit	UM	Business assumption					Total	MTD	BOSD	ECD
				Year1	Year2	Year3	Year4	Year5		100%		
Cost reduction /avoidance	Improve Fab Yield(wafer scrap preven)											
	A MO case estimate			38	32	26	20	15				
	B.Per MO case lost		NT$M	0.30	0.30	0.30	0.30	0.30				
	Profit amount=A'B	7.9	NT$M	11.4	9.6	7.8	6.0	4.5				
	SubTotal	7.86	NT$M	11.4	9.6	7.8	6.0	4.5	39.3			
	Cost saving of Investment to barcode rack											
	A Barcode Rack			20	40	0.5	0.5	0.5				
	B.Per Barcode Rack Cost		NT$M	0.36	0.36	0.36	0.36	0.36				
	C.RFID Rack			20	40	0.5	0.5	0.5				
	D.Per Barcode Rack Cost		NT$M	0.20	0.20	0.20	0.20	0.20				
	Profit amount=(A*B)-(C*D)	2.0	NT$M	3.2	6.4	0.1	0.1	0.1				
	SubTotal	1.97	NT$M	3.2	6.4	0.1	0.1	0.1	9.8			
People productivity gain	# of man power saving											
	A.Man power of DL			200	400	800	800	800				
	B.Efficient improve		%	1.67	1.67	1.67	1.67	1.67				
	C.Man power saving	10.0	in month	3.3	6.7	13.3	13.3	13.3				
	D.DL Salary(monthly)	66.0	NTD(K)	66.0	66.0	66.0	66.0	66.0				
	E.FAB number	1		1	1	1	1	1				
	Profit amount(=C*D*E*12/1000)	7.9	NT$M	2.6	5.3	10.6	10.6	10.6	39.6			
	Total	17.7	NT$M	14.0	14.9	18.4	16.6	15.1	88.7			

There is a brand new program named "RFID300" which is used to sustain the connection between the TCS300 and the RFID reader. Operators can read/write the content of the RFID tag from OMI, OMI will send the commands to the TCS and the TCS will ask RFID300 to execute the read/write commands.

5. Performance evaluation

Compared with the traditional tag system, the greatest benefit of using RFID is the cost reduction, including the initial cost and the sustaining cost. Take FAB (300 mm) as an example. Based on the information provided by MTB, FAB can save US$ 2.8M by adopting RFID to identify a WIP lot in the initiation phase. A breakdown of the cost comparison with smart tag shown in Table 6.

The cost saving between smart tag and an RFID system is clear. In this section, it will try to compare the benefits of RFID over a barcode system for MO prevention. Take FAB (200 mm) as an example. By the learning curve mode, the MO case will be an inverse ratio to the work year of operation, and the history performs as the mode. Table 7 presents an analysis of the "people productivity" and "cost reduction/avoidance", which only happens on barcode lot identification. Table 8 shows categories of FAB RFID 'read fail' events, it categorizes the top eight causes of RFID "read fail" events in FAB, over a period of 18 days. It identified that the immature equipment software introduces the root cause in the tab.

Asyst's smart-tag pilots lots through the FAB by communicating lot and processing data to the operator, manufacturing equipment, and factory automation systems. The smart-tag replaces paper travelers with a compact, battery-operated microcomputer featuring a large graphic LCD, operator interface buttons, 132 kbytes of memory, and 2-way infrared communication. The benefits of FAB-RFID displayed in detail in Table 9.

6. Conclusions

In this research, it proposed an IoT based CIM system used deep learning method into FAB that semiconductor company used RFID into 300-mm FAB, The result of this research is to incorporate deep learning method in the IoT system into the current CIM system to reveal the benefits in FAB.

This new technology has following contributions:

1. The proposed methods use IoT RFID technology is better than barcode smart tag systems. It estimate to save about US$ 2.8M by adopting IoT RFID instead of tagging to identify a work in process lot in the initiation phase.
2. People productivity: Save manpower of DL to manipulate barcodes in preparing, printing, attaching, exchanging, discarding, tracking and waiting for double check lots. Need no exchange between SMIF and non-SMIF environment.
3. Cost reduction/avoidance: Reduce M.O. cases which come from lot id cassette operation.
4. It can work with equipment engineers and equipment vendors to improve the reading quality of RFID tags in both hardware and software.

For a 300-mm RFID test-lot solution, the database needs to keep all test lot data until the next query. Thus, it have to consider the issue of data size. It is a trade-off between RFID storage capacity and database space. The other challenge is that the higher frequency of transaction could increase server response time. In the future work, how to reduce the transaction response times should be the next step to take into consideration.

Declaration of competing interest

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to https://doi.org/10.1016/j.asoc.2020.106065.

CRediT authorship contribution statement

Yu-Qiang Chen: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Biao Zhou:** Conceptualization, Methodology, Data Curation, Software. **Mingming Zhang:** Formal analysis, Data Curation, Software. **Chien-Ming Chen:** Formal analysis, Validation, Writing - original draft, Writing - review & editing.

References

[1] Y.L. Chang, H. Chang, TSMC RFID solution design for 300mm FAB, in: TSMC MIT e-Operations Symposium, 2004.
[2] Z.k. Li, R. Gadh, B.S. Prabhu, Applications of RFID technology and smart parts in manufacturing, in: Design Engineering Technical Conferences and Computers and Information in Engineering Conference, ASME, 2004.
[3] M. Lin, P.D. Cheng, R. Lin, J. You, Use RFID as a lot identification system with low cost and high feasibility, in: TSMC MIT e-Operations Symposium, 2004.
[4] H.M. Kuq, F.N. Wu, Implementation of test lot for RFID solution, in: TSMC MIT e-Operations Symposium, 2004.
[5] C.J. Huang, FAB10 detail design document for FAB10 RFID project, in: TSMC MIT e-Operations Symposium, 2014.
[6] R. Lin, Rfid solution of project initiation, TSMC China Project, 2008.
[7] K. Guo, Q. Zhang, Fast clustering-based anonymization approaches with time constraints for data streams, Knowl.-Based Syst. 46 (2013) 95–108.
[8] X. Chen, C. Jian, Gene expression data clustering based on graph regularized subspace segmentation, Neurocomputing 143 (2014) 44–50.
[9] W.h. Guo, J. Li, G.l. Chen, Y. Niu, C.Y. Chen, A PSO-optimized real-time fault-tolerant task allocation algorithm in wireless sensor networks, IEEE Trans. Parallel Distrib. Syst. 26 (12) (2015) 3236–3249.
[10] Z. Shen, P.P.C. Lee, J.W. Shu, W.Z. Guo, Encoding-aware data placement for efficient degraded reads in XOR-coded storage systems: Algorithms and evaluation, IEEE Trans. Parallel Distrib. Syst. 29 (12) (2018) 2757–2770.
[11] Y. Cheng, H. Jiang, F. Wang, Y. Hua, D. Feng, W. Guo, Y. Wu, Using high-bandwidth networks efficiently for fast graph computation, IEEE Trans. Parallel Distrib. Syst. 30 (5) (2019) 1170–1183.
[12] X. Huang, W.Z. Guo, G. Liu, G. Chen, FH-OAOS: A fast 4-step heuristic for obstacle-avoiding octilinear architecture router construction, ACM Trans. Des. Autom. Electron. Syst. 21 (3) (2016) 48, 30 pages.
[13] B. Lin, W.Z. Guo, N. Xiong, G. Chen, et al., A pretreatment workflow scheduling approach for big data applications in multi-cloud environments, IEEE Trans. Netw. Serv. Manag. 13 (3) (2016) 581–594.
[14] W. Zhu, W.Z. Guo, Z. Yu, H. Xiong, Multitask allocation to heterogeneous participants in mobile crowd sensing, Wirel. Commun. Mob. Comput. (2018) 7218061, 10 pages.
[15] Y. Mo, L. Xing, Y.K. Lin, W.Z. Guo, Efficient analysis of repairable computing systems subject to scheduled checkpointing, IEEE Trans. Dependable Secure Comput. (2018) Online Publication, http://dx.doi.org/10.1109/TDSC.2018.2869393.
[16] Y. Yang, X. Liu, X. Zheng, C. Rong, W.Z. Guo, Efficient traceable authorization search system for secure cloud storage, IEEE Trans. Cloud Comput. (2018) Online Publication, http://dx.doi.org/10.1109/TCC.2018.2820714.
[17] X. Chen, A. Li, X. Zeng, W.Z. Guo, Gang Huang, Gang huang runtime model based approach to IoT application development, Front. Comput. Sci. 9 (4) (2015) 540–553.
[18] W.Z. Guo, G. Chen, Human action recognition via multi-task learning base on spatial–temporal feature, Inform. Sci. 320 (2015) 418–428.
[19] K. Guo, W.Z. Guo, Y. Chen, Q. Qiu, Q. Zhang, Community discovery by propagating local and global information based on the mapreduce model, Inform. Sci. 323 (2015) 73–93.
[20] G. Liu, X. Huang, W.Z. Guo, Y. Niu, G. Chen, Multilayer obstacle-avoiding x-architecture steiner minimal tree construction based on particle swarm optimization, IEEE Trans. Cybern. 45 (5) (2015) 989–1002.
[21] F. Luo, W.Z. Guo, Y. Yu, G. Chen, A multi-label classification algorithm based on kernel extreme learning machine, Neurocomputing 260 (2016) 313–320.
[22] S. Wang, W.Z. Guo, Robust co-clustering via dual local learning and high-order matrix factorization, Knowl.-Based Syst. 138 (2017) 176–187.
[23] G. Liu, W.Z. Guo, Y. Niu, G. Chen, X. Huang, A PSO-based-timing-driven octilinear steiner tree algorithm for VLSI routing considering bend reduction, Soft Comput. 19 (5) (2015) 1153–1169.
[24] Y. Niu, J. Chen, W.Z. Guo, Meta-metric for saliency detection evaluation metrics based on application preference, Multimedia Tools Appl. 77 (20) (2018) 26351–26369, Online Publication.
[25] J.S. Pan, C.Y. Lee, Anissa Sghaier, Medien Zeghid, Jiafeng Xie, Novel systolization of subquadratic space complexity multipliers based on toeplitz matrix–vector product approach, IEEE Trans. Very Large Scale Integr. Syst. 27 (7) (2019) 1614–1622.
[26] T.Y. Wu, C.M. Chen, K.H. Wang, C. Meng, E.K. Wang, A provably secure certificateless public key encryption with keyword search, J. Chin. Inst. Eng. 42 (1) (2019) 20–28.
[27] C.M. Chen, K.H. Wang, K.H. Yeh, B. Xiang, T.Y. Wu, Attacks and solutions on a three-party password-based authenticated key exchange protocol for wireless communications, J. Ambient Intell. Humaniz. Comput. 10 (8) (2019) 3133–3142.
[28] C.M. Chen, B. Xiang, Y. Liu, K.H. Wang, A secure authentication protocol for internet of vehicles, IEEE Access 7 (1) (2019) 12047–12057.
[29] Y. Xia, T. Chen, J. Shan, A novel iterative method for computing generalized inverse, Neural Comput. 26 (2) (2014) 449–465.
[30] D. Ye, Z. Chen, A new approach to minimum attribute reduction based on discrete artificial bee colony, Soft Comput. 19 (7) (2015) 1893–1903.
[31] M.A.J. Banu, M.N.N. Ahamed, M.B. Manivannan, et al., Detecting spammers on social networks, Int. J. Eng. Comput. Sci. 6 (2) (2017).
[32] L.H. Yang, Y.M. Wang, et al., Multi-attribute search framework for optimizing extended belief rule-based systems, Inform. Sci. 370 (2016) 159–183.
[33] Z. He, Evolutionary k-means with pair-wise constraints, Soft Comput. 20 (1) (2016) 287–301.
[34] Y. Xia, H. Leung, M.S. Kamel, A discrete-time learning algorithm for image restoration using a novel L2-norm noise constrained estimation, Neurocomputing 198 (2016) 155–170.
[35] J. Tu, Y. Xia, S. Zhang, A complex-valued multichannel speech enhancement learning algorithm for optimal tradeoff between noise reduction and speech distortion, Neurocomputing 267 (2017) 333–343.
[36] S. Zhong, T. Chen, F. He, et al., Fast Gaussian kernel learning for classification tasks based on specially structured global optimization, Neural Netw. 57 (2014) 51–62.
[37] Y. Yu, Z. Sun, Sparse coding extreme learning machine for classification, Neurocomputing 261 (2017) 50–56.
[38] N. Yuzhen, L. Wenqi, K. Xiao, CF-based optimisation for saliency detection, IET Comput. Vis. 12 (4) (2018) 365–376.
[39] S. Zhang, Y. Xia, J. Wang, A complex-valued projection neural network for constrained optimization of real functions in complex variables, IEEE Trans. Neural Netw. Learn. Syst. 26 (12) (2015) 3227–3238.
[40] Y. Xia, J. Wang, Low-dimensional recurrent neural network-based kalman filter for speech enhancement, Neural Netw. 67 (2015) 131–139.
[41] Robert L. Bogue, Use S.M.A.R.T goals to launch management by objectives plan, in: CXO, 2005.
[42] S. Zhang, Y. Xia, W. Zheng, A complex-valued neural dynamical optimization approach and its stability analysis, Neural Netw. 61 (2015) 59–67.
[43] Y. Xia, J. Wang, A bi-projection neural network for solving constrained quadratic optimization problems, IEEE Trans. Neural Netw. Learn. Syst. 27 (2) (2016) 214–224.
[44] S. Zhang, Y. Xia, Two fast complex-valued algorithms for solving complex quadratic programming problems, IEEE Trans. Cybern. 46 (12) (2016) 2837–2847.
[45] Z. Huang, Y. Yu, J. Gu, et al., An efficient method for traffic sign recognition based on extreme learning machine, IEEE Trans. Cybern. 47 (4) (2017) 920–933.
[46] .J.-S. Pan, P. Hu, S.-C. Chu, Novel parallel heterogeneous meta-heuristic and its communication strategies for the prediction of wind power, Processes 7 (11) (2019) 845, http://dx.doi.org/10.3390/pr7110845.

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