Smart Traffic Systems Using IoT

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Issues with Traffic Congestion

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  - This is equivalent to 5 days' worth of all fuel used in the US [4]

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  - This is equivalent to 5 days' worth of all fuel used in the US [4]
- Average urban commuters are stuck in traffic congestion for 34 hours and waste $713 of fuel per year [4]

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- 600 billion Rupee (8.7 billion USD) is lost per year due to traffic congestion [7]

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- 600 billion Rupee (8.7 billion USD) is lost per year due to traffic congestion [7]
- The average speed of National Highway 44 is 20 kmph (12.43 mph) even though the speed limit is 100 kmph (62 mph) [7]

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Dynamically change traffic light cycles in areas of congestion

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- Longer green light times in the direction of traffic congestion

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Dynamically change traffic light cycles in areas of congestion

- Longer green light times in the direction of traffic congestion
- Shorter green light times in directions leading into areas of congestion

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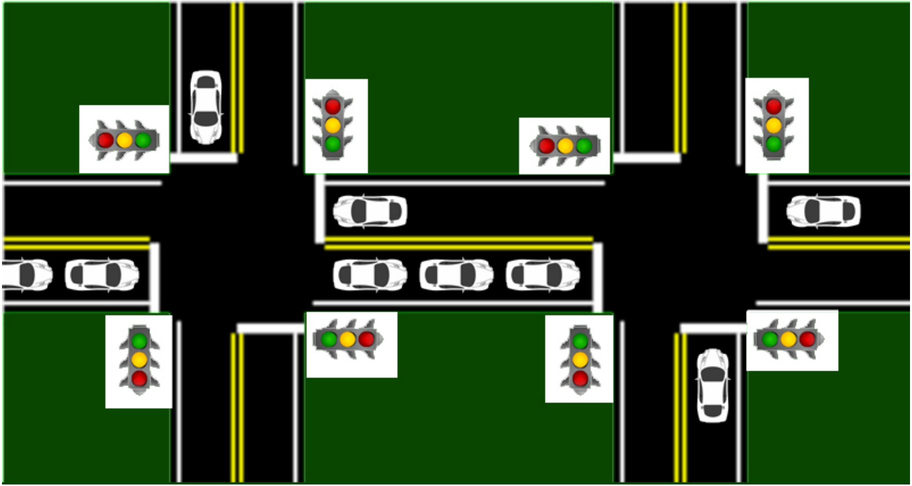

Outline

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Internet of Things (IoT)

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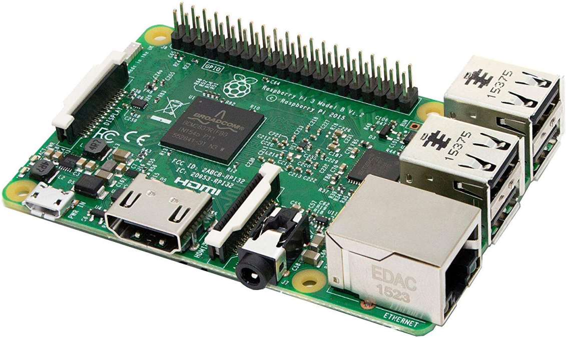
  - Have sensors that communicate with each other
  - Have sensors that connect to and receive commands from networks

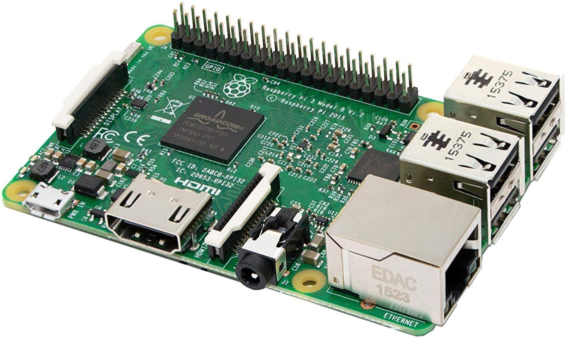
Raspberry Pi

- Single-board computer



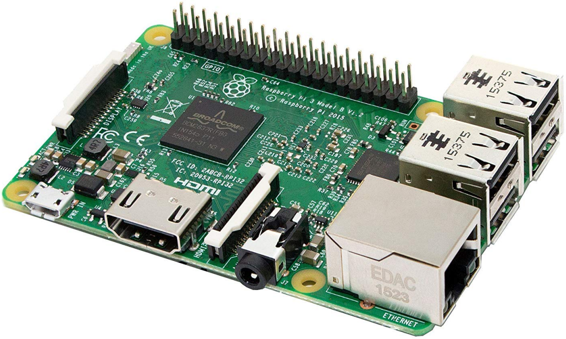
Raspberry Pi

- Single-board computer
- Uses Linux operating system



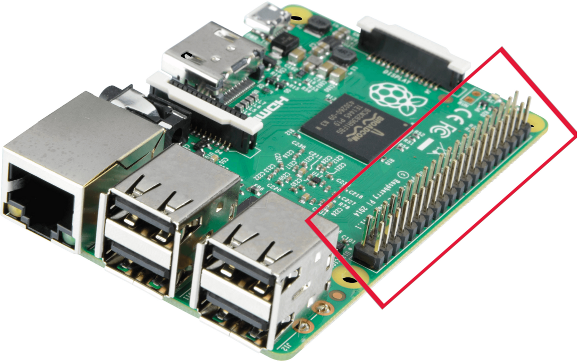
Raspberry Pi

- Single-board computer
- Uses Linux operating system
- Can be configured to send and receive signals from the internet



General Purpose Input/Output (GPIO)

- Pins that are placed at the top edge of a Raspberry Pi



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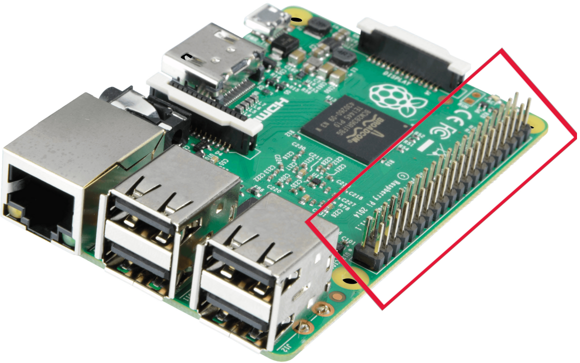
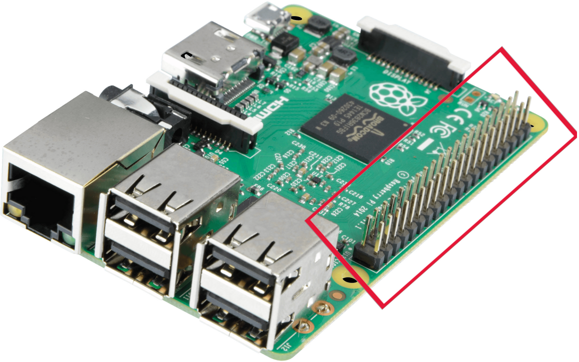
- Do not serve a specific purpose- can be customized for specific needs



General Purpose Input/Output (GPIO)

- Pins that are placed at the top edge of a Raspberry Pi
- Do not serve a specific purpose- can be customized for specific needs
- Each pin outputs a voltage when set to high



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Raspberry Pi Based System Overview

- Basuni et al.
- Requires humans to continuously interact with the system once installed

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- Uses Raspberry Pis and cameras to allow authorities to monitor traffic congestion and change traffic light times

Adding Cameras to Traffic Lights

- Cameras are placed on top of every traffic light within an intersection

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- Pictures are taken and sent to a Raspberry Pi

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- Pictures are taken and sent to a Raspberry Pi
- The length of time between pictures can be customized by authorities

Raspberry Pi Implementation

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- Has two main functions:
  1. Uses a wireless connection to a web server to transmit the camera feed.
  2. Changes the green light length of the traffic light duration
     - Two GPIO pins are used to allow for three different green light durations

Testing and Results

- System has not been tested

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- Basuni et al. strongly believe the system will reduce traffic congestion to some degree

Outline

Sensor and Server Based System

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- Doesn't require human interaction once installed

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- Uses sensors placed within road surfaces and vehicles to detect traffic congestion and automatically change traffic light cycles

Placing Sensors on Roads and Cars

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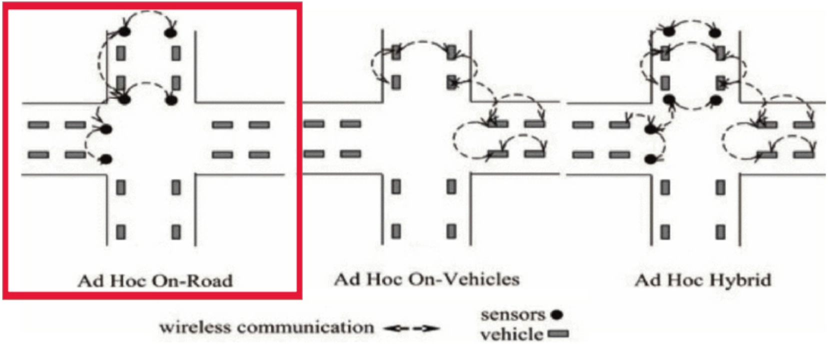
- Sensors communicate in an ad hoc system
  - Ad-hoc = components are able to connect to each other without the use of a router or base station
- Three types of ad hoc sensor networks

Placing Sensors on Roads and Cars



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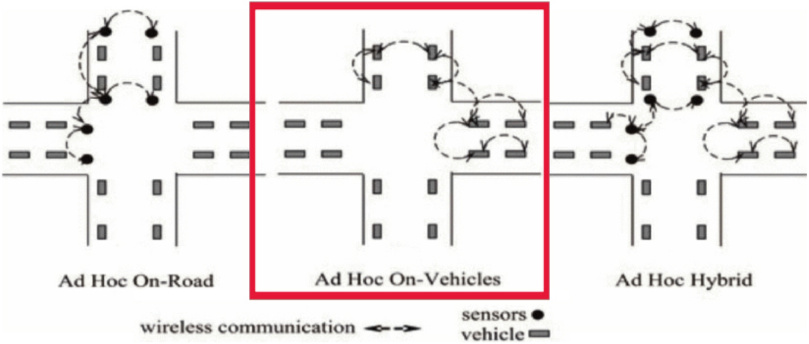

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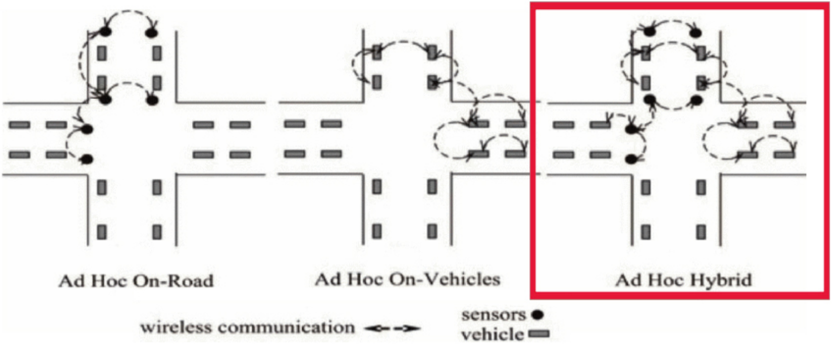

Base Station

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Base Station

- The data collected by the sensors in both the road surface and in the vehicles within the vicinity is sent to a base station via wireless connection
- The base station serves two functions:
  1. Compiles the data from the sensors and sends it to a cloud server to be analyzed
  2. Receives commands from the cloud server and change green light times in traffic lights

Green Light Time Calculation Algorithm

- Data sent to the cloud server is analyzed for signs of traffic congestion

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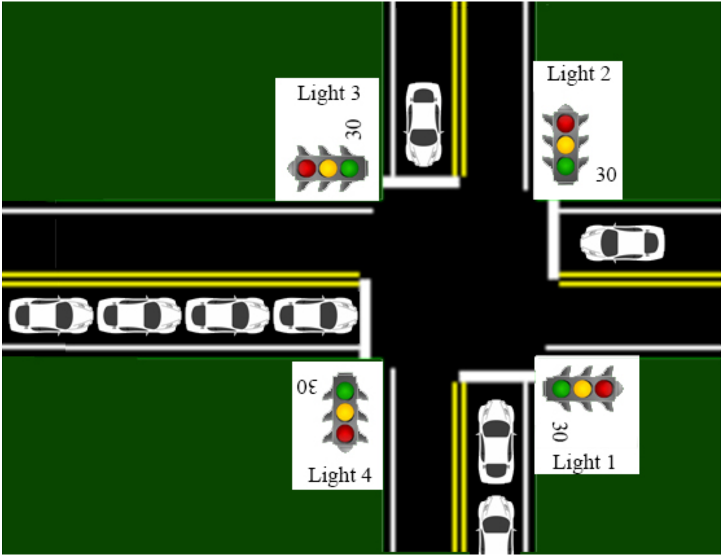
- The algorithm calculates the level of traffic congestion present and determines how long the green lights should be on in the direction of the congestion
- The algorithm calculates green light times for each traffic light in an intersection

Green Light Time Calculation Algorithm



Green Light Time Calculation Algorithm

- Current Traffic Volume (CTV) is calculated
- CTV is the total number of cars that can theoretically travel through the intersection within an hour

$$CTV = \frac{(n \times 3600)}{C}$$

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- CTV is the total number of cars that can theoretically travel through the intersection within an hour
- n is the number of cars queued in a given direction

$$CTV = \frac{(n \times 3600)}{C}$$

Green Light Time Calculation Algorithm

- Current Traffic Volume (CTV) is calculated
- CTV is the total number of cars that can theoretically travel through the intersection within an hour
- C is the traffic light cycle duration

$$CTV = \frac{(n \times 3600)}{C}$$

Green Light Time Calculation Algorithm

- Current Traffic Volume (CTV) is calculated
- CTV is the total number of cars that can theoretically travel through the intersection within an hour
- 3600 is the number of seconds in an hour

$$CTV = \frac{(n \times 3600)}{C}$$

Green Light Time Calculation Algorithm

- Current Traffic Volume (CTV) is calculated
- CTV is the total number of cars that can theoretically travel through the intersection within an hour

$$CTV = \frac{(n \times 3600)}{C}$$

$$CTV = \frac{(4 \times 3600)}{30}$$

$$CTV = 480$$

Green Light Time Calculation Algorithm

- Flow Ratio (FR) is calculated
- FR is the percent of traffic congestion present

$$FR = \frac{CTV}{MFR}$$

Green Light Time Calculation Algorithm

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- FR is the percent of traffic congestion present
- MFR is the maximum flow rate for the road in each direction

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Green Light Time Calculation Algorithm

- Flow Ratio (FR) is calculated
- FR is the percent of traffic congestion present

$$FR = \frac{CTV}{MFR}$$

$$FR = \frac{480}{500}$$

$$FR = 0.96$$

Green Light Time Calculation Algorithm

- *CTV* and *FR* is calculated for every direction going through the intersection

Green Light Time Calculation Algorithm

- *CTV* and *FR* is calculated for every direction going through the intersection
- Once completed, the results are ordered and given a priority
  - The direction with the highest *FR* is given the highest priority.

Green Light Time Calculation Algorithm

Order of priority:

1. Traffic Light 1 ($FR = 0.96$)
2. Traffic Light 2 ($FR = 0.48$)
3. Traffic Light 3 ($FR = 0.24$)
4. Traffic Light 4 ($FR = 0.24$)

Green Light Calculation Algorithm

- Effective Green Time (EGT) is calculated in every direction
- EGT is the amount of time that is used by vehicles to drive through the intersection every time the light turns green

$$EGT = FR \times C$$

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$$EGT = FR \times C$$

$$EGT = 0.96 \times 30$$

$$EGT = 28.8$$

Green Light Calculation Algorithm

- The algorithm recursively calculates the remaining three equations for each traffic light, starting with the traffic light with the highest priority

Green Light Calculation Algorithm

- Phase Green Time (PGT) is calculated
- PGT is the amount of time that is used by vehicles to drive through the intersection every time the light turns green when outside factors are accounted for

$$PGT = EGT + S - Y$$

Green Light Calculation Algorithm

- Phase Green Time (PGT) is calculated
- PGT is the amount of time that is used by vehicles to drive through the intersection every time the light turns green when outside factors are accounted for
- S is the lost time due to cars needing to accelerate from a stop after a red light

$$PGT = EGT + S - Y$$

Green Light Calculation Algorithm

- Phase Green Time (PGT) is calculated
- PGT is the amount of time that is used by vehicles to drive through the intersection every time the light turns green when outside factors are accounted for
- Y is the length of the yellow light

$$PGT = EGT + S - Y$$

Green Light Calculation Algorithm

- Phase Green Time (PGT) is calculated
- PGT is the amount of time that is used by vehicles to drive through the intersection every time the light turns green when outside factors are accounted for
- Y is the length of the yellow light

$$PGT = EGT + S - Y$$

$$PGT = 27.8 + 1 - 10$$

$$PGT = 19.8$$

Green Light Calculation Algorithm

- Remaining Green Time (RGT) is calculated
- RGT is the amount of time that is lost due to outside factors

$$RGT = EGT - PGT$$

Green Light Calculation Algorithm

- Remaining Green Time (RGT) is calculated
- RGT is the amount of time that is lost due to outside factors

$$RGT = EGT - PGT$$

$$RGT = 28.8 - 19.8$$

$$RGT = 9$$

Green Light Calculation Algorithm

- Remaining Effective Green Time ($REGT$) is calculated
- $REGT$ calculates the optimal green light time for a given traffic light

$$REGT = RGT \times \frac{CRT_{current}}{CRT_{remaining} - CRT_{previous}}$$

Green Light Calculation Algorithm

- Remaining Effective Green Time ($REGT$) is calculated
- $REGT$ calculates the optimal green light time for a given traffic light
- $CRT_{current}$ is the FR of the current traffic light being calculated for

$$REGT = RGT \times \frac{CRT_{current}}{CRT_{remaining} - CRT_{previous}}$$

Green Light Calculation Algorithm

- Remaining Effective Green Time ($REGT$) is calculated
- $REGT$ calculates the optimal green light time for a given traffic light
- $CRT_{remaining}$ is the sum of the FR for every traffic light with a lesser priority than the one currently being looked

$$REGT = RGT \times \frac{CRT_{current}}{CRT_{remaining} - CRT_{previous}}$$

Green Light Calculation Algorithm

- Remaining Effective Green Time ($REGT$) is calculated
- $REGT$ calculates the optimal green light time for a given traffic light
- $CRT_{previous}$ is the FR for traffic light that was previously looked at

$$REGT = RGT \times \frac{CRT_{current}}{CRT_{remaining} - CRT_{previous}}$$

Green Light Calculation Algorithm

- Remaining Effective Green Time ($REGT$) is calculated
- $REGT$ calculates the optimal green light time for a given traffic light

$$REGT = RGT \times \frac{CRT_{current}}{CRT_{remaining} - CRT_{previous}}$$

$$REGT = 9 \times \frac{0.96}{(0.48 + 0.24 + 0.24) - 0}$$

$$REGT = 9$$

Green Light Calculation Algorithm

- Once the algorithm finishes calculating $REGT$ the algorithm either:

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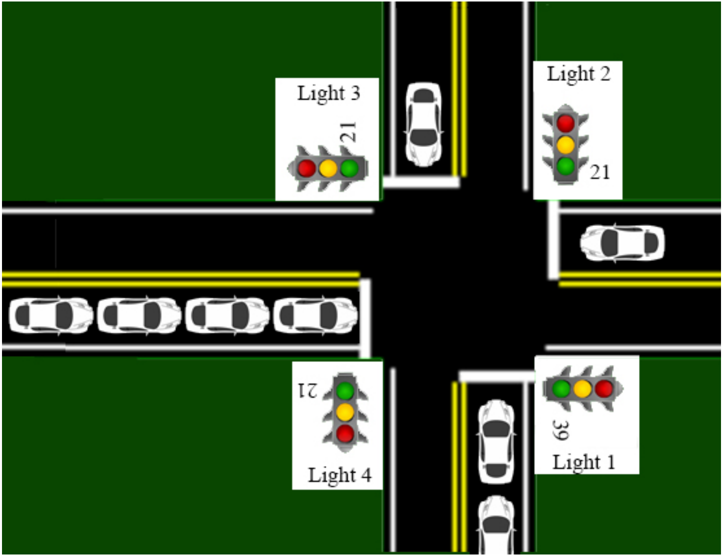
  - Calculates PGT, RGT, and $REGT$ for the traffic light with next lowest priority

Green Light Calculation Algorithm

- Once the algorithm finishes calculating $REGT$ the algorithm either:
  - Calculates PGT, RGT, and $REGT$ for the traffic light with next lowest priority
  - Sets the traffic lights within the intersection to the calculated $REGT$

Green Light Time Calculation Algorithm



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- Maximum queue size of 75 standard vehicles
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Testing and Results

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- Intersection consisted of cars traveling north, south, east, and west
- Maximum queue size of 75 standard vehicles
  - standard vehicle = 4.2 meters (13.78 feet) in length, 1.75 meters (5.74 feet) in width
- 100 light cycles were conducted, with 0 to 100 vehicles traveling in each direction every light cycle

Testing and Results

Parameters	Dynamic Algorithm	Fixed Time Algorithm	Percentage of Improved
Average Queue Length (meters)	198	620	68.06%
Average Waiting Time (seconds)	16	48	66.67%

Conclusion

- Two smart traffic systems
  - One that requires humans to maintain interaction with the system
  - One that is able to run without human interaction

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  - One that is able to run without human interaction
- The systems reduce traffic congestion
- Neither of the systems have been implemented

Acknowledgments

- Thank you to KK Lamberty and Elena Machkasova for their guidance and help throughout the entire process

References

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