Considerations of deploying AI services in a distributed method

draft-hong-nmrg-ai-deploy-05

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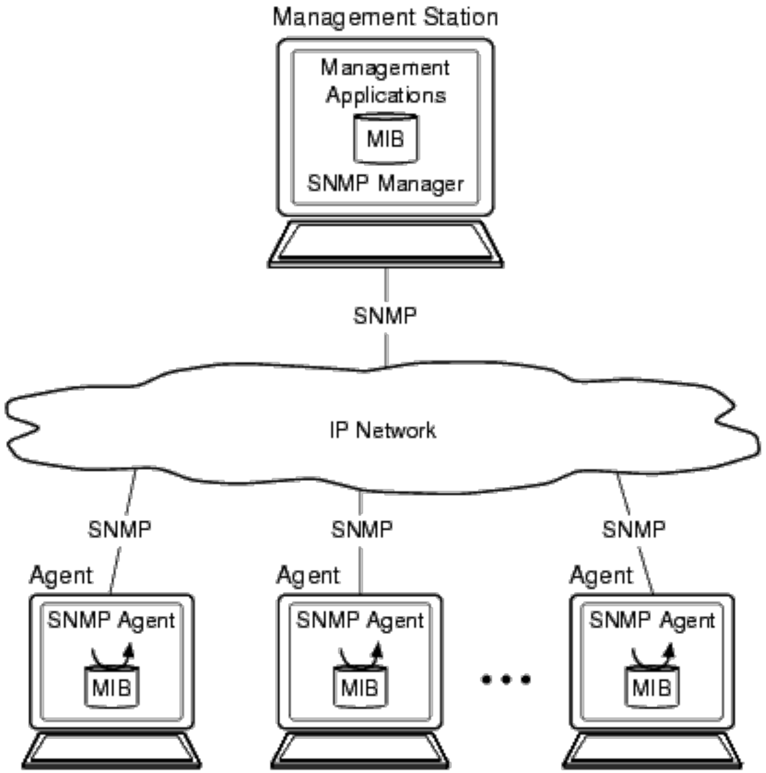
History and status

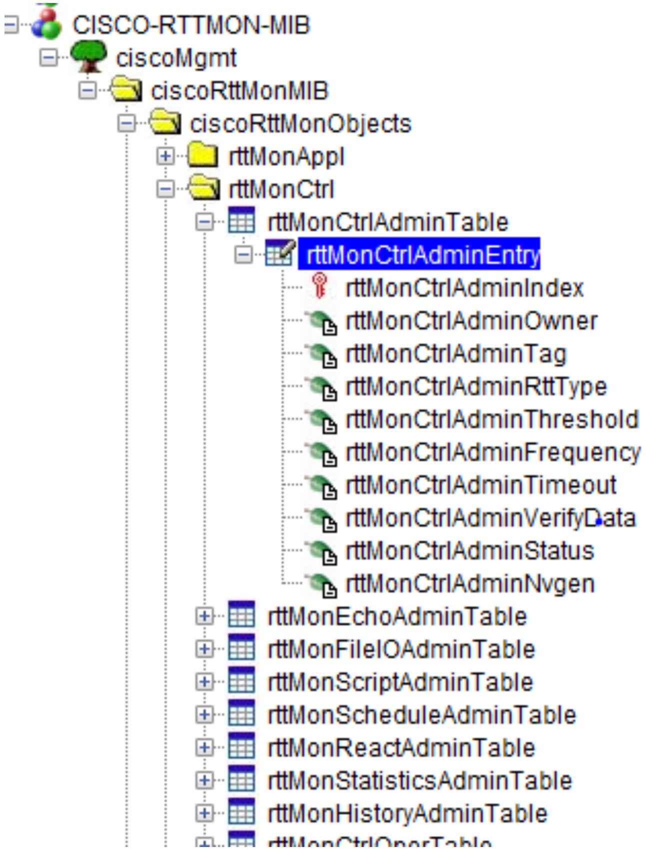
- – 00 : draft-hong-nmrg-ai-deploy-00 (Mar. 2022)
- – 1st revision : draft-hong-nmrg-ai-deploy-01 (Jul. 2022)
  - 1st presentation
- – 2nd revision : draft-hong-nmrg-ai-deploy-02 (Oct. 2022)
  - 2nd presentation
- – 3rd revision : draft-hong-nmrg-ai-deploy-03 (Mar. 2023)
  - 3rd presentation
  - Updated by comments by Alexander Clemm, Jeff Tantsura, Jeferson Campos Nobre
- – 4th revision : draft-hong-nmrg-ai-deploy-04 (Jul. 2023)
  - Updated to reflect the use case of digital twin networks
- – **5th revision : draft-hong-nmrg-ai-deploy-05 (Oct. 2023)**
  - **4th presentation**
  - **Updated to reflect the use case of digital twin networks and self-driving car**

Motivations (1/2)

SNMP-managed Configuration



[Source: Oracle]



```
CISCO-RTTMON-MIB
  ciscoMgmt
    ciscoRttMonMIB
      ciscoRttMonObjects
        rttMonAppl
        rttMonCtrl
          rttMonCtrlAdminTable
            rttMonCtrlAdminEntry
              rttMonCtrlAdminIndex
              rttMonCtrlAdminOwner
              rttMonCtrlAdminTag
              rttMonCtrlAdminRttType
              rttMonCtrlAdminThreshold
              rttMonCtrlAdminFrequency
              rttMonCtrlAdminTimeout
              rttMonCtrlAdminVerifyData
              rttMonCtrlAdminStatus
              rttMonCtrlAdminNvgen
          rttMonEchoAdminTable
          rttMonFileIOAdminTable
          rttMonScriptAdminTable
          rttMonScheduleAdminTable
          rttMonReactAdminTable
          rttMonStatisticsAdminTable
          rttMonHistoryAdminTable
          rttMonCtrlOperTable
```

[Source: StackExchange]

Motivations (2/2)

– Deployment of AI services
  - Focus : training (learning) -> inference (prediction)
  - For inference, not only high-performance servers, but also small hardware, microcontroller, low-performance CPUs, and AI chipsets are optimal target device (due to cost)

– Configuration of the system/network in terms of AI inference service
  - For training : accuracy of the model
  - For inference :
    - Target device : Local, edge, cloud
    - Objectives : Accuracy, Latency, Network traffic, Resource utilization, etc.
    - Considerations : Network configuration, AI model, Serving framework, Communication method, device capacity, inference data, etc.

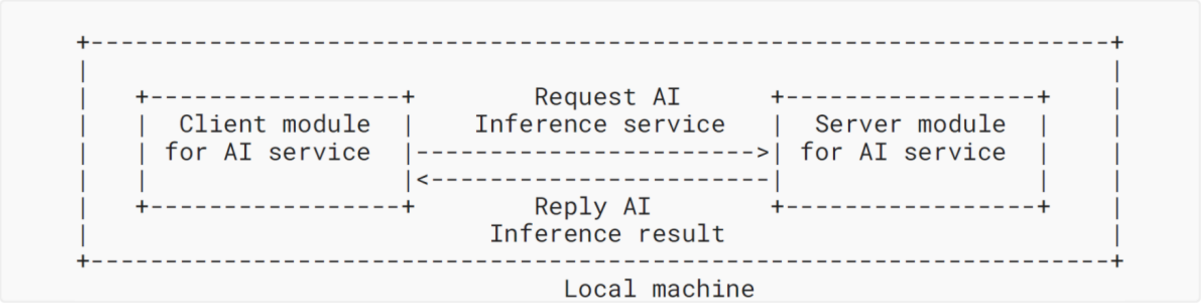
Intentions of this draft

- Share our experiences and implementation results to find optimal network/system for AI services
  - To find what is import information to provide optimal AI services
  - To find How to deliver these information between related devices

- Find common components to provide optimal AI services
  - Common information (similar to MIB)
  - Common system to provide AI services
  - Common network architecture to provide AI services
  - Common protocols to exchange information for AI services

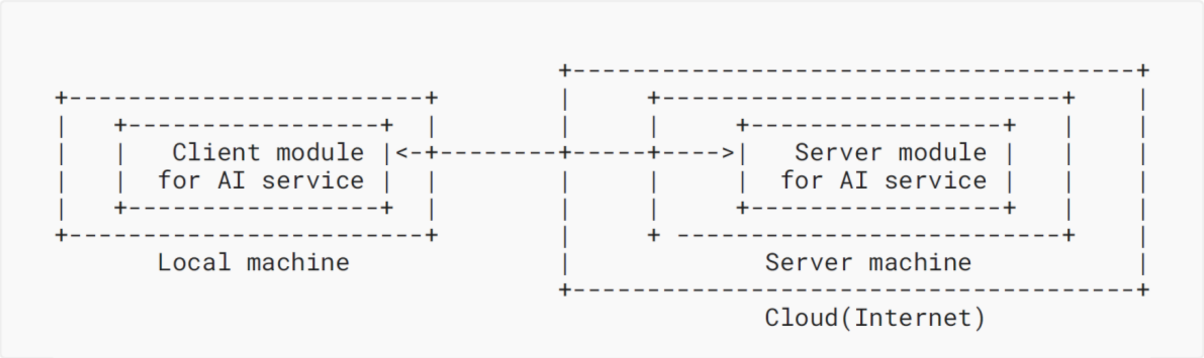
- Find useful use cases
  - Self-driving cars
  - Digital twin networks

Network configuration structure to provide AI services



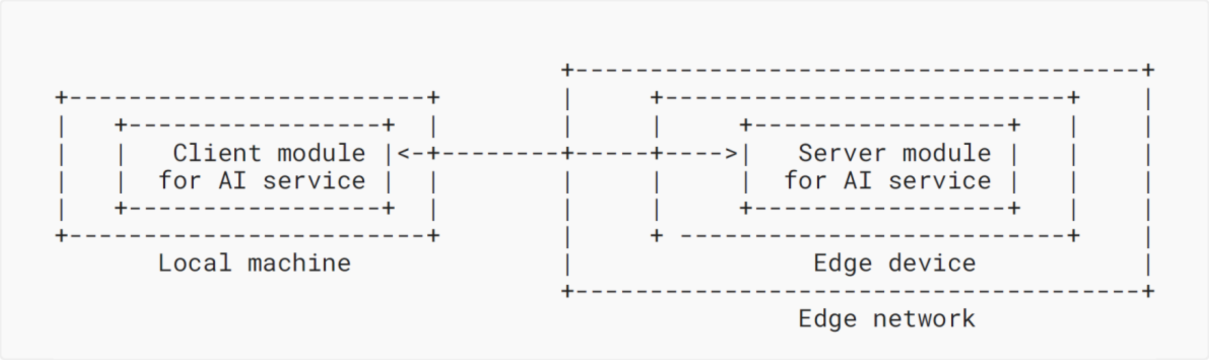
```
+------------------------------------------------------------------+
|                                                                  |
|   +-----------------+      Request AI        +-----------------+ |
|   |  Client module  |   Inference service    |  Server module  | |
|   | for AI service  |----------------------->| for AI service  | |
|   |                 |<-----------------------|                 | |
|   +-----------------+      Reply AI          +-----------------+ |
|                        Inference result                          |
+------------------------------------------------------------------+
                             Local machine
```

Figure 2: AI inference service on Local machine



```
                                  +-------------------------------------+
+------------------------+        |     +---------------------------+   |
|   +-----------------+  |        |     |     +-----------------+   |   |
|   |  Client module  |<-+--------+-----+---->|  Server module  |   |   |
|   | for AI service  |  |        |     |     | for AI service  |   |   |
|   +-----------------+  |        |     |     +-----------------+   |   |
+------------------------+        |     + --------------------------+   |
      Local machine               |           Server machine            |
                                  +-------------------------------------+
                                              Cloud(Internet)
```

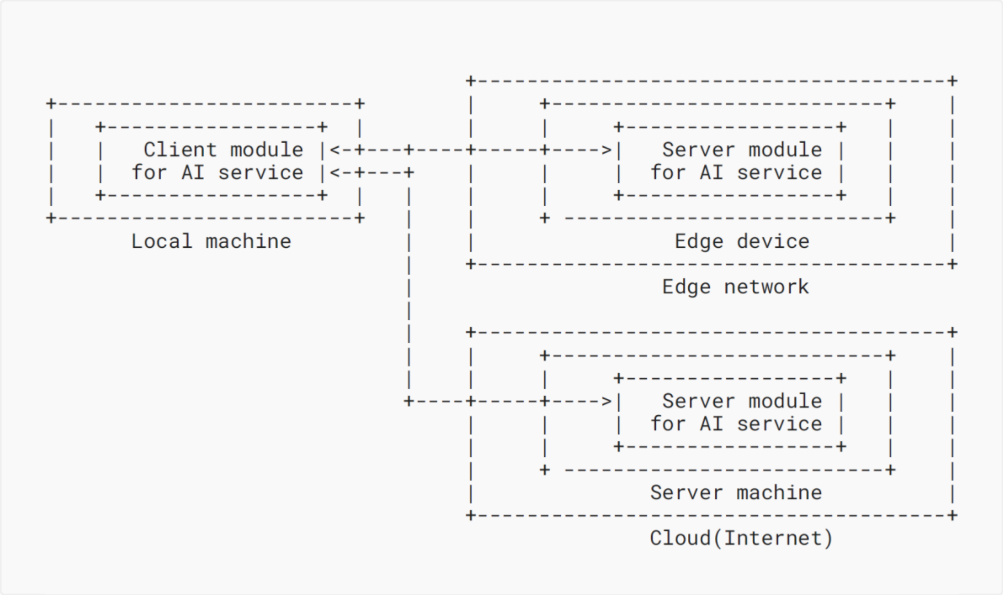
Figure 3: AI inference service on Cloud server



```
                                  +-------------------------------------+
+------------------------+        |     +---------------------------+   |
|   +-----------------+  |        |     |     +-----------------+   |   |
|   |  Client module  |<-+--------+-----+---->|  Server module  |   |   |
|   | for AI service  |  |        |     |     | for AI service  |   |   |
|   +-----------------+  |        |     |     +-----------------+   |   |
+------------------------+        |     + --------------------------+   |
      Local machine               |             Edge device             |
                                  +-------------------------------------+
                                               Edge network
```

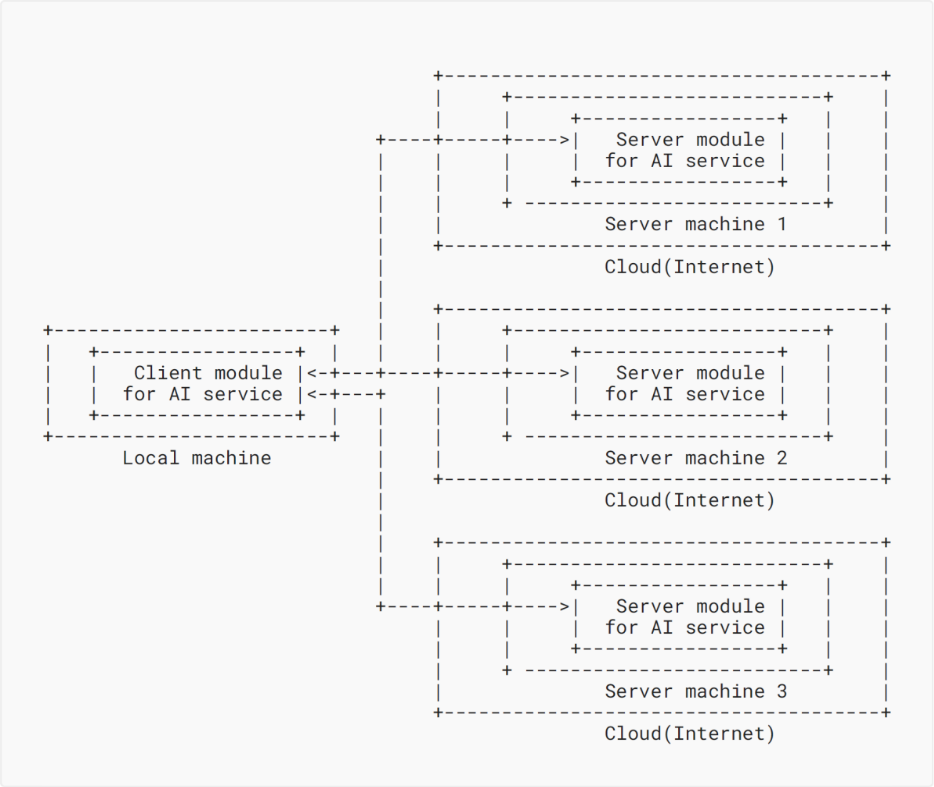
Figure 4: AI inference service on Edge device

AI inference service on vertical/ horizontal servers



```
                                  +---------------------------------------+
+------------------------+        |     +----------------------------+    |
|   +-----------------+  |        |     |     +------------------+   |    |
|   |   Client module |<-+---+----+-----+---->|   Server module  |   |    |
|   |  for AI service |<-+---+    |     |     |  for AI service  |   |    |
|   +-----------------+  |   |    |     |     +------------------+   |    |
+------------------------+   |    |     + ---------------------------+    |
       Local machine         |    |                Edge device            |
                             |    +---------------------------------------+
                             |                    Edge network
                             |    +---------------------------------------+
                             |    |     +----------------------------+    |
                             |    |     |     +------------------+   |    |
                             +----+-----+---->|   Server module  |   |    |
                                  |     |     |  for AI service  |   |    |
                                  |     |     +------------------+   |    |
                                  |     + ---------------------------+    |
                                  |              Server machine           |
                                  +---------------------------------------+
                                                 Cloud(Internet)
```

Figure 5: AI inference service on Cloud sever and Edge device



```
                                  +--------------------------------------+
                                  |     +---------------------------+    |
                                  |     |     +-----------------+   |    |
                             +----+-----+---->|  Server module  |   |    |
                             |    |     |     | for AI service  |   |    |
                             |    |     |     +-----------------+   |    |
                             |    |     + --------------------------+    |
                             |    |             Server machine 1         |
                             |    +--------------------------------------+
                             |                  Cloud(Internet)
                             |
                             |    +--------------------------------------+
+------------------------+   |    |     +---------------------------+    |
|   +-----------------+  |   |    |     |     +-----------------+   |    |
|   |   Client module |<-+---+----+-----+---->|  Server module  |   |    |
|   |  for AI service |<-+---+    |     |     | for AI service  |   |    |
|   +-----------------+  |   |    |     |     +-----------------+   |    |
+------------------------+   |    |     + --------------------------+    |
       Local machine         |    |             Server machine 2         |
                             |    +--------------------------------------+
                             |                  Cloud(Internet)
                             |
                             |    +--------------------------------------+
                             |    |     +---------------------------+    |
                             |    |     |     +-----------------+   |    |
                             +----+-----+---->|  Server module  |   |    |
                                  |     |     | for AI service  |   |    |
                                  |     |     +-----------------+   |    |
                                  |     + --------------------------+    |
                                  |             Server machine 3         |
                                  +--------------------------------------+
                                                Cloud(Internet)
```

Figure 6: AI inference service on horizontal multiple servers

Considerations according to the functional characteristics of the hardware

– The performance of AI inference service varies depending on how the hardware such as CPU, RAM, GPU, and network interface is configured for each cloud server and edge device.

– AI inference service can be deployed in the following locations
  - Distant cloud server : High performance and high cost
  - Near edge device : Medium performance and medium cost
  - Local machine : Low performance and low cost

– AI inference service result in (assumption: same AI model)
  - Distant cloud server : High accuracy, short inference time, and long delay to transmit
  - Near edge device : Medium accuracy, medium inference time, and medium delay to transmit
  - Local machine : Low accuracy, long inference time, and short delay to transmit

Considerations according to the characteristics of the AI model

– AI inference service can be deployed in the following locations

- Distant cloud server : Heavy AI model, high accuracy, Big size, long inference time
- Near edge device : Medium AI model, medium accuracy, medium size, medium inference time
- Local machine : Light AI model, low accuracy, small size, short inference time

– AI inference serving framework

- Traditional web server : ex) FastAPI, Flask, and Django
    - It can be operated on low performance machines
- Specialized serving framework : ex) Tensorflow serving
    - It can provide high performance.

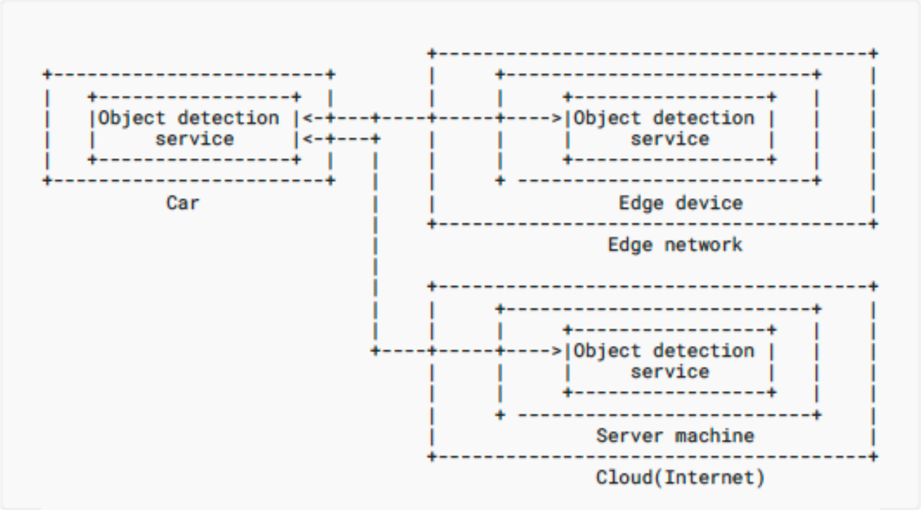
Considerations according to the characteristics of the communication method

– AI inference service can be utilized
  - Traditional REST method
    - Common and easily deployed
  - Specified communication method (e.g., gRPC)
    - Better performance but need some works

– AI Inference data can be classified
  - Real-time vs. Batch
  - Secure & non-secure

Use cases

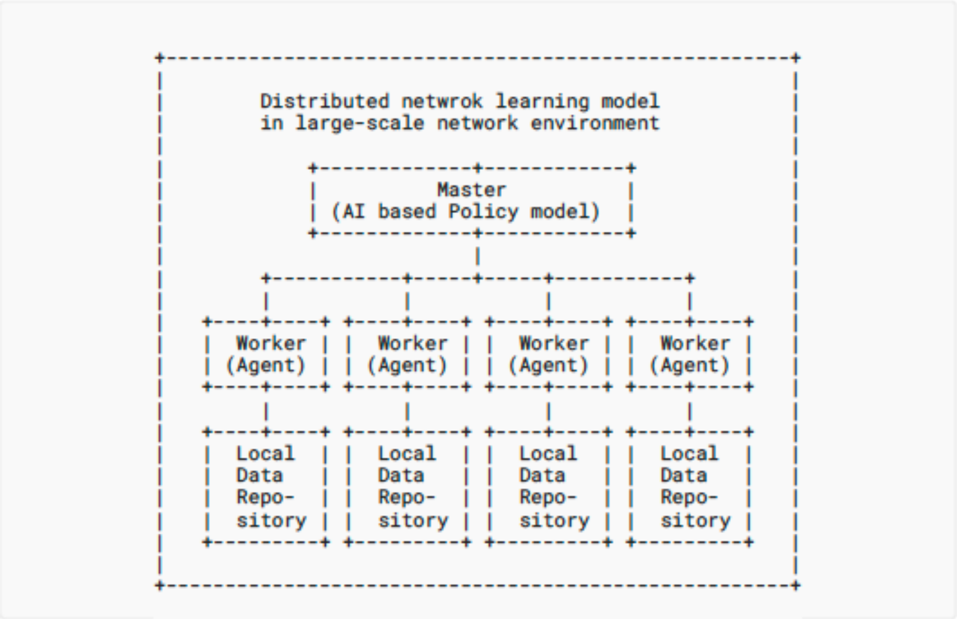
Deploying AI services in Self-driving car



```
                                  +--------------------------------------+
+------------------------+        |  +----------------------------+      |
|   +-----------------+  |        |  |     +-----------------+    |      |
|   |Object detection |<-+---+----+--+---->|Object detection |    |      |
|   |     service     |<-+---+    |  |     |     service     |    |      |
|   +-----------------+  |   |    |  |     +-----------------+    |      |
+------------------------+   |    |  +  --------------------------+      |
           Car               |    |           Edge device                |
                             |    +--------------------------------------+
                             |                Edge network
                             |
                             |    +--------------------------------------+
                             |    |  +----------------------------+      |
                             |    |  |     +-----------------+    |      |
                             +----+--+---->|Object detection |    |      |
                                  |  |     |     service     |    |      |
                                  |  |     +-----------------+    |      |
                                  |  +  --------------------------+      |
                                  |          Server machine              |
                                  +--------------------------------------+
                                             Cloud(Internet)
```

Figure 7: Distributed object detection service in self-driving car

Deploying AI services in DTN



```
+--------------------------------------------------------+
|                                                        |
|          Distributed netwrok learning model            |
|          in large-scale network environment            |
|                                                        |
|              +-------------+-------------+             |
|              |           Master          |             |
|              |  (AI based Policy model)  |             |
|              +-------------+-------------+             |
|                            |                           |
|         +-----------+------+-----+-----------+         |
|         |           |            |           |         |
|    +----+----+ +----+----+ +----+----+ +----+----+    |
|    | Worker  | | Worker  | | Worker  | | Worker  |    |
|    | (Agent) | | (Agent) | | (Agent) | | (Agent) |    |
|    +----+----+ +----+----+ +----+----+ +----+----+    |
|         |           |           |           |         |
|    +----+----+ +----+----+ +----+----+ +----+----+    |
|    | Local   | | Local   | | Local   | | Local   |    |
|    | Data    | | Data    | | Data    | | Data    |    |
|    | Repo-   | | Repo-   | | Repo-   | | Repo-   |    |
|    | sitory  | | sitory  | | sitory  | | sitory  |    |
|    +---------+ +---------+ +---------+ +---------+    |
|                                                        |
+--------------------------------------------------------+
```

Figure 8: Distributed learning model of network learning for Digital twin network

Thanks!!

Questions to NMRG

1. Is it useful and appropriate in NMRG?

2. How to develop this draft?

3. Any feedbacks?