

Full Report of Service Disruption on 26 February 2017

1. Introduction

On 26 February 2017, a power interruption at one mobile switching data center caused service disruption of China Mobile Hong Kong Company Limited (“CMHK”) network partially. This full report provides a description of events that led to the occurrence of service disruption, the remedial actions taken and the improvement measures to be taken.

2. Service Disruption on 26 February 2017

2.1 Events Leading to the Occurrence of the Outage

On 26 February 2017, the industrial building, where one CMHK mobile switching data center was located, had a scheduled power maintenance. The maintenance period was from 09:00 to 18:00 between which city power for the whole building was unavailable. CMHK had received prior notice of this event from building management office. On the day, sufficient diesel fuel and vendor support was arranged to stand by on site. The diesel generator was started up manually at 08:45. The mobile switching data center was powered by the diesel generator at 09:00.

At 13:46, high temperature alarm was alerted in the generator (reached 90 °C). By the time when on-site vendor support engineer was checking the alarm, the generator was shut down automatically at 13:48, due to high temperature protection mechanism (reached 95 °C). Under normal operation, the backup batteries of DC power system at data center should maintain the power supply for the data center. During the incident, 4 out of 5 battery banks had the output MCCB’s (Molded Case Circuit Breakers) tripped. This resulted in major power outage for the data center, and all major network equipment were shut down without power.

After cooled down of generator, on-site vendor support engineer started up the generator again. The power supply from generator was resumed at 14:14.

During the power outage between 13:48 and 14:14, limited mobile network service could be provided by the redundant network equipment at other data centers, but network quality was degraded due to network congestion. However, all prepaid services were disrupted. Some customers experienced no 2G/4G network in certain areas and attached to 3G network. Voice calls were failed in 2G/3G/4G network sometimes. Data services and VAS services including voicemail, SMS and MMS for customers in 2G/3G/4G network was partially affected, due to network congestion.

By the time when power resumed at 14:14, network equipment started to recover, but some network nodes did not resume properly after systems were powered up. The major service interruptions are mentioned below:

- a) Weak 2G/4G network coverage: Two BSC's (Base Station Controllers) and some 2G/4G cell sites were down. 2G/4G network coverage was affected. However, customers could still use 3G network. The 2G/4G network coverage was improved when we recovered the two BSC and most of the failed sites after 17:00.
- b) Occasional 4G network attachment failure: One HSS (Home Subscriber Server) node was found unstable after powered up. Customers could not attach to 4G network sometimes, due to this unstable HSS. However, customers could still attach to 3G network. The 4G network attach was improved after we isolated the unstable HSS at 16:09.
- c) All prepaid services unavailable: The prepaid system could not resume after powered up. All prepaid services became unavailable. Prepaid voice and data services were resumed after prepaid system bypass was activated around 16:00.
- d) Mobile to mobile outgoing voice call failure: The redundant MNP (Mobile Number Portability) platform was failed. The malfunction of mobile number dipping caused mobile to mobile voice call failure. The outgoing call resumed gradually, after the MNP platform was

recovered by 15:55.

2.2 Event History Log

Time	Event Description
26-Feb-2017	
08:45	Started up diesel generator manually
08:48	Power supply for mobile switching center was manually switched over to generator.
09:55	City power was stopped.
13:46	High Temperature Alarm (90 °C) was triggered, and on-site vendor support engineer checked the generator.
13:48	Generator was shut down automatically, due to the high temperature protection mechanism (95 °C). CMHK engineer noticed power outage in the mobile switching data center. NOC noticed major network outage, and triggered internal emergency escalation procedure. Support engineers started trouble shooting.
13:50-14:30	Checking the affected network services: many voice call failure, prepaid service failure, and some VAS services including voicemail, PRBT, SMS, MMS were affected partially. Data service was ok.
14:07-14:14	Vendor support engineer restarted the generator after cooled down, and power was resumed for data center.
14:10-14:30	CMHK frontline were briefed with the incident in order to answer customers' enquiries, and PR team was informed to prepare public announcement of service disruption.
14:20-14:25	CMHK engineer switched on the 4 x MCCB's for the backup battery banks of DC power system again.
14:24	Confirmed voicemail and PRBT services were resumed.
14:25	Confirmed PS core nodes resumed at the affected data center
14:30-15:30	CEO, Network Division Heads and more support engineers arrived at NOC center and the affected data center, in order to support the remedial actions for network recovery
14:30-14:40	NOC Manager informed OFCA about the major network outage
14:40	Requested core network equipment vendors to dispatch support engineers for on-site support.

15:10	Found all connections of MNP platform down, and escalated to vendor support.
15:43	Terminated the Gy connection between prepaid system and PGW, in order to resume prepaid data service (i.e. bypassed Prepaid system).
16:09	Found many error signals from one HSS node, which degraded 4G network attach successful rate. The unstable HSS node was isolated, and the redundant HSS at another data center took up all traffic load. 4G network attach successful rate started to improve.
16:23	Modified the CAMEL configuration in HLR to bypass prepaid system, and prepaid voice service was resumed.
17:15	Resumed the two failed BSC after system reload
19:45	Confirmed remaining 45 base station sites were still down. The impact on 2G/4G network coverage was minimized. Support engineers continued to recover the sites one by one.
22:20	Prepaid system was recovered, and prepaid services were gradually resumed with charging.
27-Feb	
04:22	Recovered the unstable HSS, and resumed the redundant HSS nodes in load sharing operation
05:30	The failed base station sites except 5 minor sites were all recovered (N.B. the 5 minor sites were all recovered by 28-Feb)

2.3 Remedial Actions taken

The diesel generator was shut down at 13:48, due to high temperature protection mechanism. It was started up again after cooled down, and power to mobile switching data center was resumed at 14:14. The four tripped MCCB's of battery banks were switched on again by 14:25.

At the time when power resumed at 14:14, some network equipment was found not in normal operation after system powered up. Below remedial actions had been taken to address the service impact:

- a) Weak 2G/4G network coverage in some areas: Two failed BSC were resumed successfully by 17:15 after system reload by vendor. Most

of the failed cell sites were recovered, and 45 sites were still down by 19:45. The network coverage impact had been minimized. Staff continued the trouble shooting and tried to recover the remaining failed cell sites one by one. By midnight, 12 failed sites remained. Only 5 minor sites were still failed by 05:30 on 27-Feb. These 5 minor sites were all recovered by 28-Feb.

- b) Occasional 4G network attachment failure: A pair of HSS nodes at different data centers were working in load sharing mode. It was found that the signal traffic of one HSS was abnormal, and the unstable HSS was isolated at 16:09. All traffic was then handled by the redundant HSS at another data center, and 4G network attachment successful rate started to resume. The unstable HSS was recovered later, and load sharing of redundant HSS nodes was re-activated by 04:22 on 27-Feb.
- c) All prepaid services unavailable: The prepaid system was down, and could not be recovered immediately. Prepaid data service was resumed at 15:43 by stopping the Gy connection between Prepaid system and PGW. The prepaid voice service was resumed at 16:23 by changing the CAMEL setting in HLR to bypass prepaid system. Both bypass actions enabled Prepaid customers to use data and voice services without charging in prepaid system. The prepaid system was finally recovered for service by 22:20, and prepaid voice and data charging was resumed.
- d) Mobile to mobile outgoing voice call failure: The MNP platform was failed to recover after power resumed. After trouble shooting, the MNP platform was rebooted successfully by 15:55. With MNP dipping worked again, mobile outgoing voice calls were resumed gradually.

2.4 Root cause analysis

a) Diesel Generator

In preparation of the scheduled building power maintenance, the diesel generator was checked twice by maintenance vendors on 7-Feb and 23-Feb respectively. The generator was started up for normal operation without any problem identified in both maintenance checks. On 26-Feb, the generator was started up manually at 08:45 and operating normally

till 13:46 when high temperature alarm (reached 90 °C) was alerted. The generator was then automatically shut down at 13:48 due to high temperature protection mechanism (reached 95°C).

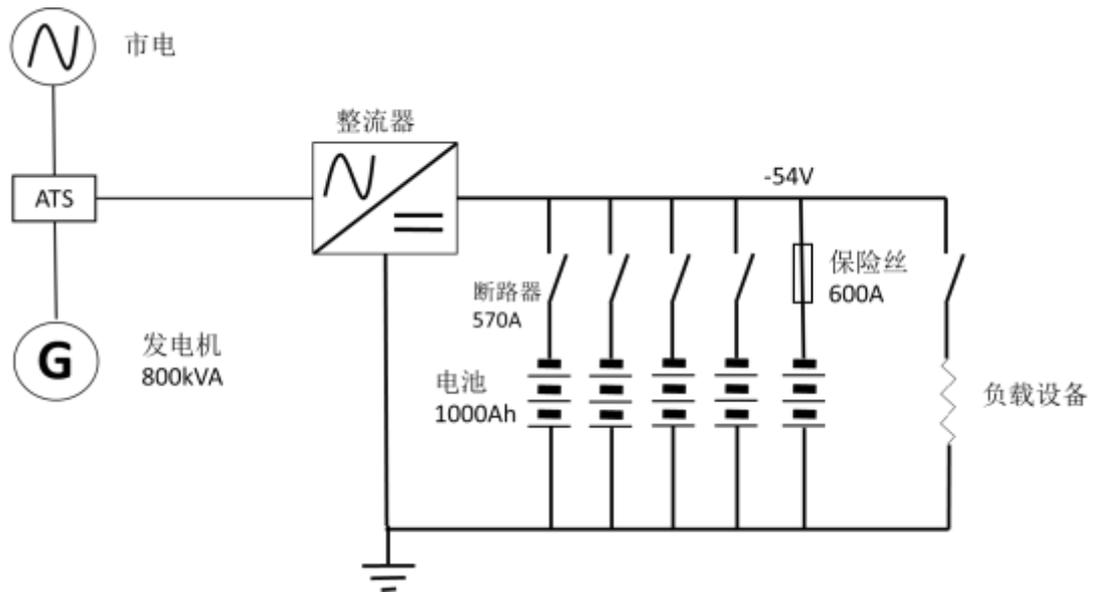
The capacity of diesel generator is 800KVA, and the output load was around 670A at the time of high temperature alarm. The generator was started up again after the cooling water temperature was down to 80°C. The cooling water temperature was maintained at this level after restarted, and the output loading was around 650A.

Dummy load test with 800A tunable loading was carried out on 1-Mar-2017 for investigation. The high temperature alarm (reached 90°C) occurred when the load exceeded 650A. After consultation with the generator's manufacturer, the maintenance vendor replaced the cooling water temperature sensor and tightened the V-Fan Belt on 8-Mar-2017. After these remedial actions, dummy load test with 800A loading was carried out and confirmed the healthy operation of generator. The cooling water temperature was maintained at around 70°C during the load test. Vendor concluded that the loose of V-Fan Belt tension causing poor ventilation was the root cause of this incident.

b) Backup batteries of DC Power Plant

The last preventive maintenance of DC power system and electrical system at the mobile switching data center was done in 29-Dec-2016 and 7-Feb-2017 respectively. No problem was identified during the regular checks.

There are 5 banks of backup batteries (@1000AH) installed for the DC power system, which should maintain the power supply for the data center in event of both city power and generator failure. Below shows the connectivity of the DC power system. The DC power system consists of rectifiers (整流器) to convert AC into DC power for telecom network equipment. The current load was about 1900A (DC current) before the incident.



The output of four battery banks are connected each with 570A MCCB, which were all tripped during the incident. One battery bank is connected with a 600A fuse which was not broken. Vendor investigation of root causes was ongoing and not conclusive. Vendor had provided below possible reasons at the moment:

- The 5 battery paths are not resistance matching rendering an unbalance load among them. Some battery path took up current larger than its breaker rating during the load discharging, which resulted in MCCB tripped.
- As all MCCB's of 4 battery banks were tripped, the load current drawn from the remaining battery bank was instantly very high, and make the discharge voltage rapidly dropped below 40V before the fuse burnt out. The function of Low Voltage Disconnection (LVD) was activated to isolate this battery bank.

Further component isolation and physical tests were needed to investigate the root causes further. The recommended immediate actions are reduction of DC power load in the center, addition of two new battery banks, and upgrade of the 570A breaker to 1250A protection fuse per battery bank. This will increase the backup battery capacity, and increase each battery bank's tolerance margin. Battery Discharge tests will then be conducted for all battery banks, and the unbroken 600A fuse will also be isolated for further root cause analysis.

c) Some network equipment problem after power resumption

Some of the network equipment was not resumed properly after power resumed from the sudden power outage. As per equipment vendors' advice, below are the main reasons.

- Two BSC's: The APG system of each failed BSC, which mainly provided input-output function and boot server for Central Processor (CP), was not started up properly. Vendor support followed outage recovery procedure to power off/on APG manually, and then the CP of each BSC could start up automatically and system resumed.
- Unstable HSS: The node was found unable to deliver some diameter messages after powered up. The node was isolated and performed zone reload after midnight for full recovery.
- Prepaid system: The cached data was lost at the sudden power outage, causing large scale of data corruption in Oracle databases. It took long time to rebuild all Oracle databases with backup data.
- MNP system: The MNP database was corrupted at the sudden power outage. Vendor support needed to reboot the system for a few times and finally recovered with the backup data.

2.5 Number of affected customers

The power outage incident majorly affected 2G/4G network coverage, mobile outgoing voice calls and prepaid services, due to some network equipment problems during power outage and after power resumed. The impact of no 2G/4G network coverage was minimized, as customers could attach to 3G network. Data services, mobile terminating calls, SMS and MMS services were partially affected because of network congestion and reduced network coverage in some areas.

Based on network statistics, the total number of active customers attached in CMHK 2G/3G/4G network has been decreased by a maximum of 336,734 during the incident period, as compared with previous Sunday. These affected customers could not log on CMHK network and use any network service.

Based on voice CDR (Call Detailed Record) analysis, the number of

unique customers with voice CDR between 14:00 and 17:30 was decreased by 337,560. So, the number of affected customers for voice service is estimated at 337,560. This figure may overlap partially with the above-estimated 336,734 customers who could not log on CMHK network during the incident.

4. Communication with the Public

CMHK had communicated with customers, local media, and the general public about the service disruption via the following channels on the day of the incident.

1. Retail, Corporate Sales and Hotline staff
2. Corporate Website
3. Facebook Post
4. Media

4.1 Retail, Corporate Sales and Hotline staff

At around 14:15 on Feb 26, we started to brief all Frontline staff about the incident to facilitate them for handling related enquiries from customers. In Hotline operation, we immediately mobilized resources and arranged overtime to handle the influx of customers' enquires.

We also prepared and uploaded IVR announcement at 8:10pm to inform customers that the service was gradually resuming

中國移動香港於今日較早前曾出現電力配套故障事宜，導致客戶既流量數據及話音服務受到影響，現經搶修後，有關服務已陸續回復正常。本公司對受影響的客戶深表歉意。

We updated another IVR announcement at 10:09pm to inform customer that service has been resumed right after the service recovery

中國移動香港於今日較早前曾出現電力配套故障事宜，導致客戶之流量數據及話音服務受到影響，經搶修後，有關服務已回復正常。本公司對受影響的客戶深表歉意。

The respective IVR announcement was removed at 11:53pm.

4.2 Corporate Website

Messages and announcements were posted in CMHK official Corporate Website and Facebook during and after the incident, informing customers of the network service disruption and service recovery status.

The first announcement was posted on CMHK corporate website at 3:39pm.

由於電力配套出現故障，導致客戶之數據及話音服務可能受到影響。本公司現正盡力搶修，對受影響的客戶深表抱歉。不便之處，敬請原諒。 Due to power unit distribution problem, customers' voice and data services may be affected. We are taking remedial actions and please accept our sincere apologies for the inconvenience caused.

The second announcement was posted on CMHK corporate website at 7:00pm.

中國移動香港於今天較早前曾出現電力配套故障事宜，導致客戶之流動數據及話音服務受到影響，現經搶修後，有關服務已陸續回復正常。本公司對受影響的客戶深表歉意。

Due to power unit distribution problem which occurred earlier today, China Mobile Hong Kong sincerely apologize to those customers whose voice and data services may have been affected. After emergency repair, the affected services are now recovering successively.

The full recovery announcement was posted on CMHK corporate website at 9:35pm.

由於今天下午出現電力配套故障問題，引致客戶的話音及流動數據服務受到影響，我們對受影響的客戶深表歉意。經全力搶修後，有關服務已回復正常。對於為客戶帶來不便，本公司深感抱歉。我們會繼續努力，堅守為客戶帶來更優質的服務體驗。

Due to power system problem which occurred earlier this afternoon, we sincerely apologize to those customers whose voice and data services may have been affected. After emergency repair, the affected services have now resumed. We will continue our efforts and pledge to bring better service experience to our customers.

4.3 Facebook Post

The first announcement was posted on CMHK Facebook page at 3:04pm.

由於電力配套故障，導致客戶嘅數據及話音服務可能受到影響。我哋現正盡力搶修，對受影響客戶深表抱歉。不便之處，敬請原諒。

Due to power unit distribution problem, customers' voice and data services may be affected. We are taking remedial actions and please accept our sincere apologies for the inconvenience caused.

The second announcement was posted on CMHK Facebook page at 7:30pm.

今日較早曾出現嘅電力配套故障事宜，導致客戶嘅流動數據及話音服務受到影響，現經搶修後，有關服務已陸續回復正常。我哋對受影響嘅客戶深表歉意。

Due to power unit distribution problem which occurred earlier today, China Mobile Hong Kong sincerely apologize to those customers whose voice and data services may have been affected. After emergency repair, the affected services are now recovering successively.

The full recovery announcement was posted on CMHK corporate website at 9:55pm.

今日曾出現嘅電力配套故障事宜，影響到客戶嘅話音及流動數據服務，我們對受影響嘅客戶深表歉意。經全力搶修後，有關服務已回復正常。為客戶帶來不便，我們深感抱歉。

Due to power system problem which occurred today, we sincerely apologize to those customers whose voice and data services may have been affected. After emergency repair, the affected services have now resumed.



China Mobile Hong Kong
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【21:55 #CMHK更新】
今日曾出現嘅電力配套故障事宜，影響到客戶嘅話音及流動數據服務，我們對受影響嘅客戶深表歉意。經全力搶修後，有關服務已回復正常。為客戶帶來不便，我們深感抱歉。

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【19:30 #CMHK更新】
今日較早曾出現嘅電力配套故障事宜，導致客戶嘅流動數據及話音服務受到影響，現經搶修後，有關服務已陸續回復正常。我哋對受影響嘅客戶深表歉意。

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由於電力配套故障，導致客戶嘅數據及話音服務可能受到影響。我哋現正盡力搶修，對受影響客戶深表抱歉。不便之處，敬請原諒。

4.4 Media

CMHK had kept informing the media about the latest situation and recovery status and immediately responded to their queries during and after the incident.

The first media statement was issued at 3:20pm.

由於電力配套出現故障，導致中國移動香港的客戶數據及話音服務可能受到影響。本公司現正盡力搶修，對受影響的客戶深表抱歉。不便之處，敬請原諒。

Due to power unit distribution problem, China Mobile Hong Kong's voice and data services may be affected. We are taking immediate remedial actions and please accept our sincere apologies for the inconvenience caused.

The second media statement (full recovery) was issued at 9:30pm.

由於今天下午出現電力配套故障問題，引致客戶的話音及流動數據服務受到影響，中國移動香港對受影響的客戶深表歉意。經全力搶修後，有關服務已回復正常。對於為客戶帶來不便，本公司深感抱歉。我們會繼續努力，堅守為客戶帶來更優質的服務體驗。

Due to the power system problem, which occurred earlier this afternoon, China Mobile Hong Kong sincerely apologize to those customers whose voice and data services may have been affected. After emergency repair, the affected services have now resumed. We will continue our efforts and pledge to bring better service experience to our customers.

5. Improvement Measures

- For the generator, the checking and tightening of V-Fan Belt tension will be done at least once per year, in addition to the visual check of belt tension during monthly preventive maintenance. Apart from the annual load test in maintenance contract, a dummy full load test will be arranged before every planned city power outage of the building in future.
- For the DC power system, two new battery banks was added on 16-Mar-2017 and all 570A MCCB's will be replaced by 1250A fuses by

18-Mar-2017. Also, we have speeded up the network migration and powered off some unused equipment earlier. The DC current load has been reduced from 1900A to 1720A.

- Dummy full load tests had already been arranged for all generators at other CMHK data centers in these 2 weeks after the incident, and no major problem was found. We will also complete full power audit for CMHK data centers in March 2017.
- The new network equipment supporting MNP has been implemented earlier, and can now act as an emergency backup for MNP function in case of existing MNP platform failure. The MNP platform will eventually be replaced by the new nodes with site resiliency by Q2 2017 in the planned network migration.
- The Prepaid system will be migrated to a new system with site resiliency by end 2017.
- To strive for a better, stable and advanced network to serve customers, CMHK is now migrating to a new core network with 100% site resiliency of network equipment including BSC, which will be completed by Q3 2017. The new redundant core network equipment will be located at different new data centers with more secure power facilities. We will speed up the migration, in order to offload traffic and services from this vulnerable switching data center as early as possible.

China Mobile Hong Kong Co. Ltd.

Date: 16-Mar-2017