SIT742 Assignment 2

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1. Prerequisites

Follow the installation instructions here (https://gist.github.com/ololobus/4c221a0891775eaa86b0) to install the following:

- Apache Spark 2.1.0
- Python 2.7
- Java 1.8

In addition, the following third-party python packages are installed:

- GeoIP2 (http://geoip2.readthedocs.io/en/latest/) to extrapolate IP information
- UserAgents (https://pypi.python.org/pypi/user-agents) to extrapolate User Agent information
- Networkx (https://networkx.readthedocs.io) to visualise the findings

These can be installed using `pip` :

```
$ pip install geoip2 pyyaml ua-parser user-agents networkx
```

Alterinatively, attach using the Databricks library importer.

2. Getting Started

2.1. Package Imports

Begin by importing all necessary packages.

```
import networkx as nx
import matplotlib.colors as colors
import matplotlib.pyplot as plt
import numpy as np
from datetime import datetime
from user_agents import parse as ua_parse
from pyspark.mllib.fpm import FPGrowth
```

2.2 Loading data from S3 bucket

To begin with, we need to load the data from an S3 bucket, `sit742-htweblog-gz` . I unzipped the data and compressed it using strong gzip compression from the given zip file, as per:

```
$ unzip /path/to/HTWebLog.zip
$ gzip -r /path/to/HTWebLog -9
```

I referred to this guide (https://docs.databricks.com/user-guide/dbfs-databricks-file-system.html#mounting-an-s3-bucket) for assistance with mounting Databricks into the S3 bucket. I refer to the constant `PATH_TO_S3_MOUNT` to refer to the S3 mount in Databricks.

```
# Define constant to path of log data
PATH_TO_S3_MOUNT = '/mnt/htweblog'

# Check if we have already mounted our S3 Bucket
htweblog_s3_mounted = len(filter(lambda mount: mount.mountPoint == PATH_TO_S3_MOUNT, dbutils.fs.mounts())) == 1

if not htweblog_s3_mounted:
  # Setup AWS configuration
  ACCESS_KEY = "AKIAJDP5QWKSBKP74XUA"
  SECRET_KEY = "9c1/vI3MNniajoK7dH7ko+24Ipr47Q4S4Q5ruO9z".replace("/", "%2F")
  AWS_BUCKET_NAME = "sit742-htweblog-gz"

  # Mount S3 bucket
  dbutils.fs.mount("s3n://%s:%s@%s/" % (ACCESS_KEY, SECRET_KEY, AWS_BUCKET_NAME), PATH_TO_S3_MOUNT)

# Show mounted files
display(dbutils.fs.ls(PATH_TO_S3_MOUNT))
```

path	name
dbfs:/mnt/htweblog/geolite-db/	geolite-db/
dbfs:/mnt/htweblog/internal_requests.dot/	internal_requests.dot/
dbfs:/mnt/htweblog/sample-set/	sample-set/
dbfs:/mnt/htweblog/u_ex140801.log.gz	u_ex140801.log.gz
dbfs:/mnt/htweblog/u_ex140802.log.gz	u_ex140802.log.gz
dbfs:/mnt/htweblog/u_ex140803.log.gz	u_ex140803.log.gz
dbfs:/mnt/htweblog/u_ex140804.log.gz	u_ex140804.log.gz
dbfs:/mnt/htweblog/u_ex140805.log.gz	u_ex140805.log.gz
dbfs:/mnt/htweblog/u_ex140806.log.gz	u_ex140806.log.gz

2.3. Setting constants

To begin we need to find where our data is located. I created the constant `SERVER_LOGS_GZIP_FILES` to point to where each log file is.

We can use a sample of the data using the `SAMPLE_LOGS_GZIP_FILES` , controlling whether to use a sample set (i.e., first 10 log files) using the `USE_SAMPLE_SET` constant, which is `False` if we should use all data (for final submission) or `True` for development and debugging purposes.

In addition, we will use *GeoIP2 (http://dev.maxmind.com/geoip/)* to extrapolate information about the client's IP. This requires downloading the GeoLite2 Cities Database (http://geolite.maxmind.com/download/geoip/database/GeoLite2-City.mmdb.gz). This has been downloaded in the S3 Bucket as `GeoLite2-City.mmdb` .

```
GEOLITE_CITIES_DB_FILE = '/dbfs/' + PATH_TO_S3_MOUNT + '/geolite-db/GeoLite2-City.mmdb'
SAMPLE_LOGS_GZIP_FILES = PATH_TO_S3_MOUNT + '/sample-set/*.log.gz'
SERVER_LOGS_GZIP_FILES = PATH_TO_S3_MOUNT + '/*.log.gz'
# Change this to False if we want to run on the entire dataset, otherwise keep to True for testing/debugging
USE_SAMPLE_SET = False
```

3. Data Acquisition

3.1. Extract Data

Extract the files from the `SERVER_LOGS_GZIP_FILES` as an *Apache Spark RDD (http://spark.apache.org/docs/latest/programming-guide.html#resilient-distributed-datasets-rdds)*, then caching (http://spark.apache.org/docs/latest/quick-start.html#caching) it for better performance. Note that we can utilise reading directly from within the gzip, as per the external datasets (http://spark.apache.org/docs/latest/programming-guide.html#external-datasets) guide.

```
# If USE_SAMPLE_SET, then read from sample set directory, otherwise use all data
data_files = SAMPLE_LOGS_GZIP_FILES if USE_SAMPLE_SET else SERVER_LOGS_GZIP_FILES
print("Using %s set files at: %s" % ('sample' if USE_SAMPLE_SET else 'full', data_files))
# Load in Apache Spark RDD (Resillient Distributed Dataset)
logs_rdd = sc.textFile(data_files, use_unicode=False)
# Caching the data to a cluster-wide in-memory cache
logs_rdd.cache()
```

```
Using full set files at: /mnt/htweblog/*.log.gz
Out[12]: /mnt/htweblog/*.log.gz MapPartitionsRDD[35] at textFile at NativeMethodAccessorImpl.java:0
```

Extracting the fields from the dataset file (using the `Fields` comment):

```
# Strip fields from dataset, underscoring each instead of dasherizing it
fields  = (logs_rdd
           .filter(lambda line: line.startswith('#Fields:'))
           .map(lambda line: line.replace('-', '_'))
           .first()
           .split(' ')
          )[1:]
fields
```

```
Out[13]:
['date',
 'time',
 's_ip',
 'cs_method',
 'cs_uri_stem',
 'cs_uri_query',
 's_port',
 'cs_username',
 'c_ip',
 'cs(User_Agent)',
 'sc_status',
 'sc_substatus',
 'sc_win32_status',
 'time_taken']
```

3.2. Transform Data

Tranform the data by zipping the contents with each value, thereby producing a structured format of the key/value pair of each log entry. Also perform additional transformation on the dataset, such as:

- converting relevant integer strings into actual `int` s,
- converting the `date` and `time` fields into one `timestamp` field, as a `DateTime` object, and
- making the `cs(User_Agent)` field a little nicer to work with by changing it to just `user_agent`

```
def map_integers(record):
    """Maps integer types in the record from unicode strings"""
    record['s_port'] = int(record['s_port'])
    record['sc_status'] = int(record['sc_status'])
    record['sc_substatus'] = int(record['sc_substatus'])
    record['sc_win32_status'] = int(record['sc_win32_status'])
    record['time_taken'] = int(record['time_taken'])
    return record

def map_timestamp(record):
    """Maps a record's date and time into one timestamp"""
    record['timestamp'] = datetime.strptime(record.pop('date') + record.pop('time'), '%Y-%m-%d%H:%M:%S')
    return record

def map_user_agent(record):
    """Maps the user agent field to be better used"""
    record['user_agent'] = record.pop('cs(User_Agent)')
    return record

# Map dataset contents (log lines) as dictionary from fields, then map using additional map functions
data = (logs_rdd
        .filter(lambda line: not line.startswith('#'))
        .map(lambda line: dict(zip(fields, line.split(' '))))
        .map(map_integers)
        .map(map_timestamp)
        .map(map_user_agent)
       )
```

3.3 Load Data

Load the data as a structured data frame (http://spark.apache.org/docs/latest/sql-programming-guide.html#datasets-and-dataframes) from its RDD, registering the data under the `Log` in-memory table. To load it, we will need to map each record as a Row (https://spark.apache.org/docs/1.1.1/api/python/pyspark.sql.Row-class.html) type.

```
logs_df = data.toDF()
logs_df.registerTempTable("Log")
# Cache the table for improved performance
sqlContext.cacheTable("Log")
# Show that the table has been registered
sqlContext.sql("DESCRIBE TABLE Log").show()
```

```
+---------------+---------+-------+
|       col_name|data_type|comment|
+---------------+---------+-------+
|           c_ip|   string|   null|
|      cs_method|   string|   null|
|   cs_uri_query|   string|   null|
|    cs_uri_stem|   string|   null|
|    cs_username|   string|   null|
|           s_ip|   string|   null|
|         s_port|   bigint|   null|
|      sc_status|   bigint|   null|
|   sc_substatus|   bigint|   null|
|sc_win32_status|   bigint|   null|
|     time_taken|   bigint|   null|
|      timestamp|timestamp|   null|
|     user_agent|   string|   null|
+---------------+---------+-------+
```

3.4. Additional Data Extraction

We can extract the distinct user agents from the log and load this into its own table, `UserAgent` .

```
def map_user_agent_partition(partition):
    """Maps a parition of IP addresses"""
    def map_user_agent(user_agent_str):
        """Maps the user agent in a record to extrapolate more specific information about the client platform"""
        agent_lookup = ua_parse(user_agent_str)
        return {
          'user_agent': user_agent_str,
          'user_agent_browser_name': agent_lookup.browser.family,
          'user_agent_browser_version': agent_lookup.browser.version_string,
          'user_agent_os_name': agent_lookup.os.family,
          'user_agent_os_version': agent_lookup.os.version_string,
          'user_agent_device_brand': agent_lookup.device.brand,
          'user_agent_device_model': agent_lookup.device.model,
          'user_agent_device_family': agent_lookup.device.family,
          'user_agent_is_pc': agent_lookup.is_pc,
          'user_agent_is_smartphone': agent_lookup.is_mobile,
          'user_agent_is_tablet': agent_lookup.is_tablet,
          'user_agent_is_bot': agent_lookup.is_bot
        }
    return [map_user_agent(record['user_agent']) for record in partition]

# Select all unique user agents from the logs
user_agents_rdd = sqlContext.sql('SELECT DISTINCT user_agent FROM Log WHERE user_agent IS NOT NULL').rdd
# Map user agents them using the mapping function above
user_agents_df = user_agents_rdd.mapPartitions(map_user_agent_partition).toDF()
# Register the dataframe as a table, UserAgent
user_agents_df.registerTempTable("UserAgent")
# Cache the table for improved performance
sqlContext.cacheTable("UserAgent")
# Show that the table has been registered
sqlContext.sql("DESCRIBE TABLE UserAgent").show()
```

```
+--------------------+---------+-------+
|            col_name|data_type|comment|
+--------------------+--------+-------+
|          user_agent|  string|   null|
|user_agent_browse...|  string|   null|
|user_agent_browse...|  string|   null|
|user_agent_device...|  string|   null|
|user_agent_device...|  string|   null|
|user_agent_device...|  string|   null|
|   user_agent_is_bot| boolean|   null|
|    user_agent_is_pc| boolean|   null|
|user_agent_is_sma...| boolean|   null|
|user_agent_is_tablet| boolean|   null|
|  user_agent_os_name|  string|   null|
|user_agent_os_ver...|  string|   null|
+--------------------+--------+-------+
```

Similarly, we can extract all the IP addresses into the `IPAddr` table.

```
def map_ip_address_partition(partition):
    """Maps a parition of IP addresses"""
    # Must re-import geoip as mapping within new context
    # Refer to: http://stackoverflow.com/a/33755564/519967
    from geoip2 import database as geoipdb
    geoip_reader = geoipdb.Reader(GEOLITE_CITIES_DB_FILE)
    def map_ip_address(ip_address):
      """Maps a single IP address to extrapolate more specific information about the IP"""
      try:
        ip_lookup = geoip_reader.city(ip_address)
        return {
          'ip_address': ip_address,
          'country_code': ip_lookup.country.iso_code,
          'country_name': ip_lookup.country.name,
          'state_code': ip_lookup.subdivisions.most_specific.iso_code,
          'state_name': ip_lookup.subdivisions.most_specific.name,
          'city_name': ip_lookup.city.name,
          'lat': ip_lookup.location.latitude,
          'lng': ip_lookup.location.longitude
        }
      except:
          return None
    result = [map_ip_address(record['ip']) for record in partition]
    # Must close reader!
    geoip_reader.close()
    return result

# Select all unique user agents from the logs, then map them using the mapping function above
ip_addrs_rdd = sqlContext.sql("SELECT DISTINCT c_ip AS ip FROM Log WHERE c_ip IS NOT NULL").rdd
# Map using mapPartitions functions, removing those countries we can't find (i.e., private IP address)
ip_address_df = ip_addrs_rdd.mapPartitions(map_ip_address_partition).filter(lambda record: record != None).toDF()
# Register the dataframe as a table, UserAgent
ip_address_df.registerTempTable("IPAddr")
# Cache the table for improved performance
sqlContext.cacheTable("IPAddr")
# Show that the table has been registered
sqlContext.sql("DESCRIBE TABLE IPAddr").show()
```

```
+------------+---------+-------+
|    col_name|data_type|comment|
+------------+---------+-------+
|   city_name|   string|   null|
|country_code|   string|   null|
|country_name|   string|   null|
|  ip_address|   string|   null|
|         lat|   double|   null|
|         lng|   double|   null|
|  state_code|   string|   null|
|  state_name|   string|   null|
+------------+---------+-------+
```

We can see that data has now be loaded by counting the records of our three tables.

```
 sqlContext.sql("SELECT COUNT(*) AS count_of_logs         FROM Log").show()
 sqlContext.sql("SELECT COUNT(*) AS count_of_user_agents  FROM UserAgent").show()
 sqlContext.sql("SELECT COUNT(*) AS count_of_ip_addresses FROM IPAddr").show()
```

```
+-------------+
|count_of_logs|
+-------------+
|     73368256|
+-------------+

+--------------------+
|count_of_user_agents|
+--------------------+
|               57870|
+--------------------+

+---------------------+
|count_of_ip_addresses|
+---------------------+
|               522416|
+---------------------+
```

3.5. Persist Data

As I am using the free Databricks tier, where the cluster will restart after a few hours inactivity, I persisted the data so that I can work on the assignment over multiple days without re-loading the data. To do this, I persisted the data frames using the following:

```
logs_df.write.mode("ignore").saveAsTable("Log")
ip_address_df.write.mode("ignore").saveAsTable("IPAddr")
user_agents_df.write.mode("ignore").saveAsTable("UserAgent")
```

Then when I want to work with the data, cache it (https://docs.databricks.com/spark/latest/sparkr/functions/cacheTable.html) for improved query performance:

```
sqlContext.cacheTable("IPAddr")
sqlContext.cacheTable("UserAgent")
sqlContext.cacheTable("Log")
```

4. Informational Resource Transaction Extraction

4.1. Defining a user session

To extract session information, we generate a new field, the `session_idenfitier` , which is a hash-delimited concatenated string of the following information:

1. The client's ip, `c_ip` ,
2. The client's specific user agent string, `user_agent` ,
3. The client's session date (the `DATE` of the `timestamp`), and
4. The client's session hour (extracted using `DATE_FORMAT(timestamp, 'H')`)

We assume that one session is grouped by every hour on a specific date. We can therefore group the order of our requested URIs by the unique `session_identifier` we have created above.

One client IP may have multiple users, e.g., an internet café or the hotel lobby. Therefore we must split the client IP into sessions based on user agent. Our limitation here is that there may be two *separate* users requesting the page with the same user agent at the same IP within the same hour.

4.2. Defining which resources to mine

To ensure that we extract *informational resources* only, we add the following conditions to our request:

1. The request must return an `ashx` or `aspx` resource, not a media resource (e.g., JavaScript, Cascading Stylesheet, Image file etc.),
2. The request must not be from the `media` , `layouts` or `sitecore` admin directories as this is non-informational data,
3. The request must return a `200` response, and must not be a placeholder error page (i.e., `404.aspx` should be removed as this is non-informational)

Lowercase all the URIs to prevent case sensitiity (i.e., a user types in `/Home.aspx` vs `/home.aspx` ; semantically the same).

4.3. Functionalising the query

This is all constructed for us in the `construct_sql_query` function to keep query selection consistent and reduce duplication.

Using this function we can:

- compare the requests internally versus externally
- compare how the top three countries differ in their requests (referencing from Assignment 1 we saw these countries are `Hong Kong` , `USA` , `Australia`)
- compare how mobile versus tablet versus PC vs bot requests differ

```
def construct_sql_query(where = None, join = None):
  """ Constructs a consistent SQL query for extracting data from the database

  Args:
      where_clause (string): An optional string to add an extra WHERE clause to the query
```

```
    join_clause (string): An optional string to add an extra JOIN clause to the query
                          that must be in the format `JOIN <Table> ON <Join>`
Returns:
    string: A string to run on the database to extract data
"""
standard_query = """
  SELECT
  -- Session identifier defined as thus:
  CONCAT(
    -- [1] The client's IP address
    l.c_ip, '#',
    -- [2] The client's user agent string
    l.user_agent, '#',
    -- [3] The date of the request
    DATE(l.timestamp), '#',
    -- [4] The hour of the request
    DATE_FORMAT(l.timestamp, 'H')
  ) AS session_identifier,
  -- URI stem requested, all lowercase to prevent case sensitvity
  LCASE(l.cs_uri_stem)
  FROM Log l
  -- Add extra JOIN clause
  {join_clause}
  WHERE
    -- [1] ASHX or ASPX requests only to filter out other resources
    (l.cs_uri_stem LIKE "%.ashx" OR l.cs_uri_stem LIKE "%.aspx") AND
    -- [2] Remove media, layout templates or admin sitecore requests (non-informational resources)
    NOT (l.cs_uri_stem LIKE "%/~/media%" OR l.cs_uri_stem LIKE "%/layouts%" OR l.cs_uri_stem LIKE "%/sitecore/%") AND
    -- [3] Response codes of 200 and not the x0x pages (e.g. 404.aspx)
    (l.sc_status = 200 AND l.cs_uri_stem NOT LIKE "/%0%.aspx")
    -- Add extra WHERE clause
    {where_clause}
  GROUP BY 1, l.timestamp, l.cs_uri_stem
  ORDER BY l.timestamp
"""
```

```
  # Add an "AND" to the where clause if it exists
  where_clause = ("AND %s" % where) if where is not None else ""
  join_clause = join if join is not None else ""
  formatted_query = standard_query.format(join_clause=join_clause, where_clause=where_clause)
  # Return the formatted query
  return formatted_query


# Define IP range string for all INTERNAL requests
internal_ip_range_string = '(^127\.)|(^10\.)|(^172\.1[6-9]\.)|(^172\.2[0-9]\.)|(^172\.3[0-1]\.)|(^192\.168\.)'

sql_queries = {
  # Internal vs external
  "internal_requests": construct_sql_query(where = "l.c_ip REGEXP '%s'" % internal_ip_range_string),
  "external_requests": construct_sql_query(where = "l.c_ip NOT REGEXP '%s'" % internal_ip_range_string),
  # Top three countries
  "hk_requests": construct_sql_query(join = "JOIN IPAddr i ON l.c_ip = i.ip_address", where="i.country_code = 'HK'"),
  "us_requests": construct_sql_query(join = "JOIN IPAddr i ON l.c_ip = i.ip_address", where="i.country_code = 'US'"),
  "au_requests": construct_sql_query(join = "JOIN IPAddr i ON l.c_ip = i.ip_address", where="i.country_code = 'AU'"),
  # PC vs bots vs tablets vs smartphones
  "pc_requests":         construct_sql_query(join = "JOIN UserAgent ua ON ua.user_agent = l.user_agent",
where="ua.user_agent_is_pc"),
  "tablet_requests":     construct_sql_query(join = "JOIN UserAgent ua ON ua.user_agent = l.user_agent",
where="ua.user_agent_is_tablet"),
  "bots_requests":       construct_sql_query(join = "JOIN UserAgent ua ON ua.user_agent = l.user_agent",
where="ua.user_agent_is_bot"),
  "smartphone_requests": construct_sql_query(join = "JOIN UserAgent ua ON ua.user_agent = l.user_agent",
where="ua.user_agent_is_smartphone")
}
```

Run this as an SQL query under the SQL query context to extract the transactional data we are interested in. Map it into a `tuple` type, representing the `extracted` data as a `(Key, Value)` tuple.

Define this as a function to allow for multiple queries to be made.

```
def extract_data(sql_query):
    """ Extracts data from the database given the SQL query
    Args:
        sql_query (str): a string containing the SQL query used to extract the data.
    Returns:
        list<tuple>: a list of all records as a tuple of `(session_identifier, cs_uri_stem)`.
    """
    return sqlContext.sql(sql_query).rdd.map(lambda record: (record[0], record[1]))
```

Now extract the data for every `sql_query` in our `sql_queries`:

```
# Loop through every query and extract data
extracted_data = {key: extract_data(sql_query) for key, sql_query in sql_queries.items()}
```

5. Training the Model

We now mine for frequent patterns in our transactions Spark FPGrowth implementation.

To do this, we group all of the extracted data by the unique `session_identifier` key. The `sessionPair` is a the Key/Value pair whose key is the `session_identifier` and whose value is a unique set of the `cs_uri_stem`s accessed. This becomes our list of transactions.

To ensure we access multiple hits in a given session, we will show only those patterns with at least 3 hits in the session.

From this, we produce a list of `FreqItemset`s representing the frequency pattern of resources from the above transactions extracted, sorted in descending frequency order.

```
def train_model(extracted, min_support_level = 0.01):
    """ Train a model using the Frequency Pattern Growth imported from Spark.

    Extracts the transactions used to train the model and supply it with a provided minimum
    support level.

    Args:
        extracted (list<tuple>): a list of all extracted records from the database.
        min_support_level (float): the threshold for a `FreqItemset` to be identified as
                                   frequent, defaults to `0.01`.

    Returns:
        list<FreqItemset>: A list of the `FreqItemset` identified sorted by descending
                           frequency values.
    """
    transactions = (extracted
                    # Group by each session id
                    .groupByKey()
                    # Extract out a set of each URI hit
                    .map(lambda sessionPair: set(sessionPair[1]))
                   )
    model = FPGrowth.train(transactions, minSupport=min_support_level, numPartitions=6)
    sorted_itemsets = (model.freqItemsets()
                       # Only show item sets with 3 or more hits in the set
                       .filter(lambda itemset: len(itemset.items) >= 3)
                       # Sort in reverse order by frequencies
                       .sortBy(lambda itemset: itemset.freq, False)
                       .collect()
                      )
    return sorted_itemsets
```

Now train the models and print off each of our `FreqItemset` s. For some requests, we relax the pattern minimum support level to either 75% or 50%, as at a minimum support level is `0.01` retrieves few patterns.

```
# Set the default and relaxed min support levels
default_min_support_level = 0.01
relaxed_min_support_level = {
  "hk_requests": default_min_support_level * 0.5,
  "au_requests": default_min_support_level * 0.75,
  "smartphone_requests": default_min_support_level * 0.5,
  "pc_requests": default_min_support_level * 0.5,
  "tablet_requests": default_min_support_level * 0.5
}
# Loop through every extracted data and train using that model
sorted_itemsets = {
  key: train_model(data, min_support_level=relaxed_min_support_level.get(key, default_min_support_level))
  for key, data in extracted_data.items()
}
for key, itemset in sorted_itemsets.iteritems():
  print "%s itemset" % key
  print
  for item in itemset:
    print item
```

```
au_requests itemset

FreqItemset(items=[u'/above-and-beyond.aspx', u'/facilities.aspx', u'/rooms.aspx'], freq=152)
FreqItemset(items=[u'/above-and-beyond.aspx', u'/rooms.aspx', u'/offers.aspx'], freq=151)
FreqItemset(items=[u'/facilities.aspx', u'/rooms.aspx', u'/offers.aspx'], freq=141)
FreqItemset(items=[u'/about-the-hotel.aspx', u'/rooms.aspx', u'/offers.aspx'], freq=122)
FreqItemset(items=[u'/about-the-hotel.aspx', u'/facilities.aspx', u'/rooms.aspx'], freq=120)
FreqItemset(items=[u'/above-and-beyond.aspx', u'/dining.aspx', u'/rooms.aspx'], freq=120)
FreqItemset(items=[u'/above-and-beyond.aspx', u'/facilities.aspx', u'/offers.aspx'], freq=115)
FreqItemset(items=[u'/facilities.aspx', u'/dining.aspx', u'/rooms.aspx'], freq=107)
FreqItemset(items=[u'/above-and-beyond.aspx', u'/facilities.aspx', u'/dining.aspx'], freq=105)
FreqItemset(items=[u'/dining.aspx', u'/rooms.aspx', u'/offers.aspx'], freq=103)
FreqItemset(items=[u'/about-the-hotel.aspx', u'/above-and-beyond.aspx', u'/facilities.aspx'], freq=100)
FreqItemset(items=[u'/above-and-beyond.aspx', u'/dining.aspx', u'/offers.aspx'], freq=100)
FreqItemset(items=[u'/about-the-hotel.aspx', u'/above-and-beyond.aspx', u'/rooms.aspx'], freq=97)
FreqItemset(items=[u'/location-and-contacts.aspx', u'/rooms.aspx', u'/offers.aspx'], freq=92)
FreqItemset(items=[u'/about-the-hotel.aspx', u'/facilities.aspx', u'/offers.aspx'], freq=88)
FreqItemset(items=[u'/about-the-hotel.aspx', u'/dining.aspx', u'/rooms.aspx'], freq=85)
FreqItemset(items=[u'/facilities.aspx', u'/dining.aspx', u'/offers.aspx'], freq=79)
FreqItemset(items=[u'/our-city.aspx', u'/facilities.aspx', u'/rooms.aspx'], freq=76)
FreqItemset(items=[u'/about-the-hotel.aspx', u'/location-and-contacts.aspx', u'/rooms.aspx'], freq=74)
```

6. Visualisation of Model

6.1. Visualisation using NetworkX

Below we visualise how people navigate through the site using a Multi-Directional Network Graph (https://networkx.github.io/documentation/networkx-1.10/reference/classes.multidigraph.html).

To prevent excessive amounts of data being plotted, we can use the `frequency_threshold_percentile` variable to change how many FP Itemsets are shown. By default, only the top 25% (those with frequencies above the third percentile) will be plotted to keep the visualisations readable. Not doing so lead to unreadable graphs (https://i.imgur.com/LddbGNO.png).

The thick ends of the lines indicate the "to" direction (i.e., the line from `home` to `offers` has a thick stub toward `offers`, meaning that users would go from home to offers). The values in between each line indicate the frequency of the pattern.

```
def create_directed_network_graph(sorted_itemsets, frequency_threshold_percentile=75):
  """ Creates a directed network graph of the frequency interaction patterns.

  Args:
      sorted_itemsets (list<FreqItemset>): A list of the `FreqItemset` identified
                                           sorted by descending frequency values.

      frequency_threshold_percentile (int): The value of of the minimum percentile to accept
                                            when plotting. Defaults to the 75th percentile.

  Returns:
      tuple: A tuple containing the `NetworkX.DiGraph` and CSV representation (`string`)
             of interaction patterns: `(graph, csv)`
  """
  # Declare our new graph
  graph = nx.MultiDiGraph()

  # Declare an empty dictionary for the edge labels
  edge_labels = {}

  # CSV to be tabulated in LaTeX
  csv = "Sequence,From,To,Frequency"

  # Work out which frequencies we will plot within our threshold
  assert frequency_threshold_percentile <= 100 and frequency_threshold_percentile >= 0, "Threshold must be a percentage
between 0 and 1"
```

```
highest_frequency = sorted_itemsets[0].freq
all_frequencies = np.array([ itemset.freq for itemset in sorted_itemsets ])
# Accept the "top nth" percentile
accepted_minimum_frequency = np.percentile(all_frequencies, frequency_threshold_percentile)
# Filter out sorted_frequencies
accepted_itemsets = [itemset for itemset in sorted_itemsets if itemset.freq >= accepted_minimum_frequency]

# Define a colormap for each sequence
cmap = plt.cm.get_cmap('Set1', len(accepted_itemsets))
sequence_colors = [colors.rgb2hex(cmap(i)[:3]) for i in range(cmap.N)]

# Add in each node
for sequence, freq_itemset in enumerate(accepted_itemsets):
  # 'Clean up' the label by removing the '.aspx' and leading forward slash
  items = [label[1:-5].replace('-', ' ') for label in freq_itemset.items]
  num_items = len(items)
  # Define freq
  freq = freq_itemset.freq
  # Find the previous and following node in the set
  for i, item in enumerate(items):
    node_from, node_to = items[0 + i:2 + i]
    edge_labels[(node_from, node_to)] = freq
    # Add to our CSV
    csv = "%s\n%i,%s,%s,%i" % (csv, sequence, node_from, node_to, freq)
    label = "%i/%i" % (sequence, freq)
    graph.add_edge(node_from, node_to, weight=freq, label=label, color=sequence_colors[sequence])
    # Break the loop so we don't go out of range!
    if num_items - i == 2:
      break

# Set up the layout of the graph
pos = nx.shell_layout(graph, scale=8)

# Draw the nodes
nx.draw_networkx_nodes(graph, pos, node_size=1000)
```

```
  # Draw the edges
  nx.draw_networkx_edges(graph, pos)

  # Draw the labels
  nx.draw_networkx_labels(graph, pos, font_size=10, font_family='serif')
  nx.draw_networkx_edge_labels(graph, pos, font_family='serif', font_size=7, alpha=0.5, edge_labels=edge_labels)

  return (graph, csv)

def plot_visualisation(sorted_itemsets, frequency_threshold_percentile =75):
  """ Plots the visualisation of a specific set of sorted frequencies

  Args:
      sorted_itemsets (tuple): The sorted frequencies to visualise

      frequency_threshold_percentile (int): The value of of the minimum percentile to accept
                                            when plotting. Defaults to the 75th percentile.


  Returns:
      tuple: A tuple containing the `NetworkX.DiGraph` and CSV representation (`string`)
             of interaction patterns: `(graph, csv)`
  """
  # Clear last plotted functions
  plt.clf()

  graph, csv = create_directed_network_graph(sorted_itemsets, frequency_threshold_percentile)

  # Disable the axis and plot
  plt.axis('off')
  display(plt.show())

  return (graph, csv)
```

We can now call our function to visualise our respective graphs.

6.1.1. Internal Requests

```
graph_data = {}
graph_data["internal_requests"] = plot_visualisation(sorted_itemsets["internal_requests"])
```

6.1.2. External Requests

```
graph_data["external_requests"] = plot_visualisation(sorted_itemsets["external_requests"])
```

6.1.3. Hong Kong Requests

```
graph_data["hk_requests"] = plot_visualisation(sorted_itemsets["hk_requests"])
```

6.1.4. USA Requests

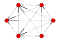
```
graph_data["us_requests"] = plot_visualisation(sorted_itemsets["us_requests"])
```

6.1.5. Australian Requests

```
graph_data["au_requests"] = plot_visualisation(sorted_itemsets["au_requests"])
```

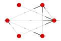
6.1.6. PC Requests

```
graph_data["pc_requests"] = plot_visualisation(sorted_itemsets["pc_requests"])
```



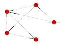
6.1.7. Smartphone Requests

```
graph_data["smartphone_requests"] = plot_visualisation(sorted_itemsets["smartphone_requests"])
```



6.1.8. Tablet Requests

```
graph_data["tablet_requests"] = plot_visualisation(sorted_itemsets["tablet_requests"])
```



6.1.9. Bot Requests

```
graph_data["bots_requests"] = plot_visualisation(sorted_itemsets["bots_requests"])
```

6.2. Improved plotting using GraphViz

However, the above is hard to read, especially the frequency values. We can convert the graph into a Graphviz (http://www.graphviz.org) diagram string. Install the dependency as needed:

```
$ brew install graphviz
```

Running the command below, we can copy the output and run through the `dot` command provided by Graphviz:

```
 $ pbpaste > a2.dot
$ dot internal_requests.dot -T pdf > internal_requests.pdf
```

```
def graph_to_pydot_string(graph, layout="dot"):
    """ Converts the graph to a representable Graphviz diagram using pydot

    Args:
        graph (`NetworkX.DiGraph`): The graph to convert

    Returns:
        string: A string representing the Graphviz diagram string with the
                layout specified, defaults to `dot`.
    """
    string = nx.drawing.nx_pydot.to_pydot(graph).to_string()
    # Split all lines to add the specified layout
    lines = string.split("\n")
    lines.insert(1, 'layout="%s";' % layout)
    return "\n".join(lines)
```

6.2.1. Internal Requests

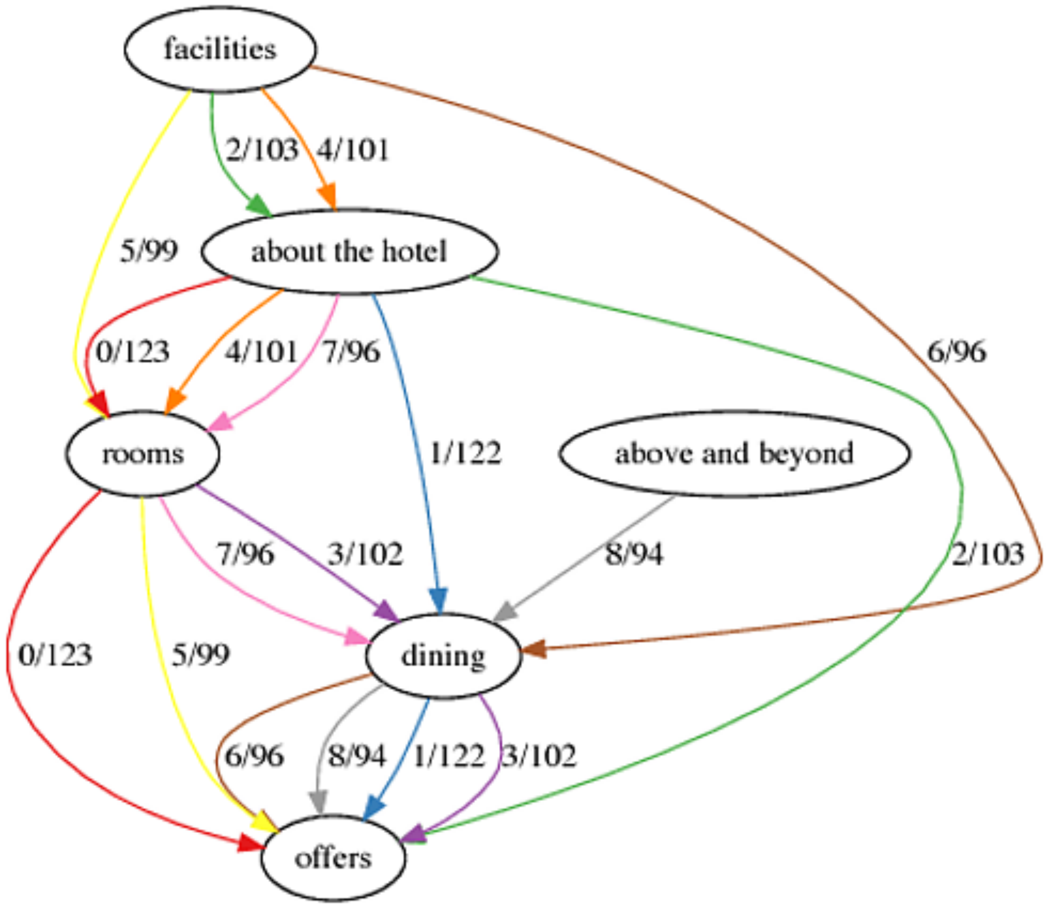
Now run our conversion function on our graph:

```
print graph_to_pydot_string(graph_data["internal_requests"][0])
```

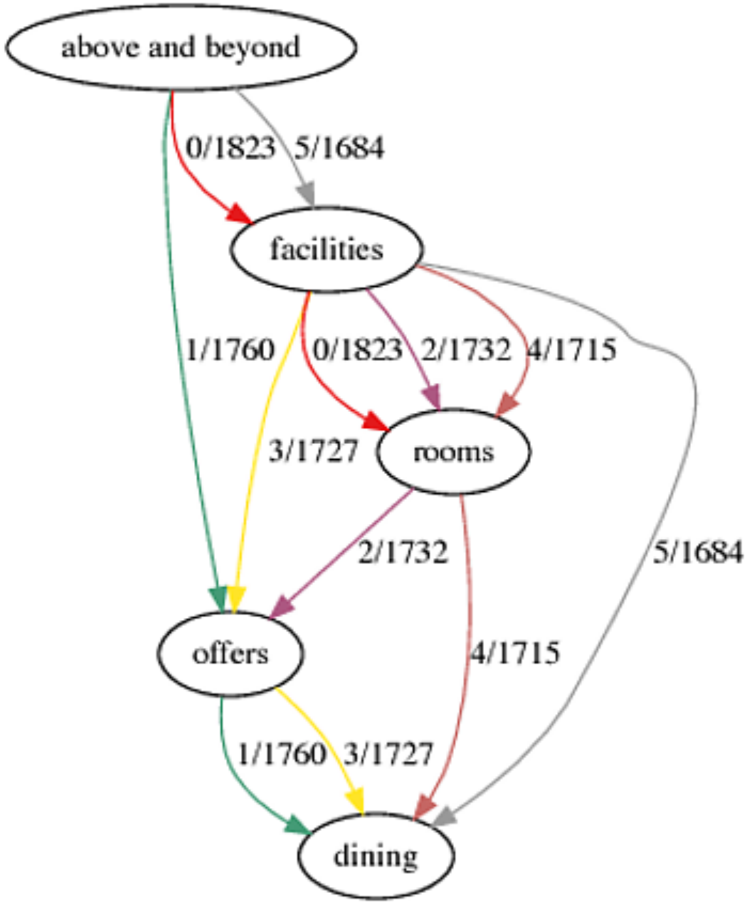
```
digraph "" {
layout="dot";
facilities;
"about the hotel";
dining;
offers;
rooms;
"above and beyond";
facilities -> dining  [color="#a65628", key=0, label="6/96", weight=96];
facilities -> rooms  [color="#ffff33", key=0, label="5/99", weight=99];
facilities -> "about the hotel"  [color="#4daf4a", key=0, label="2/103", weight=103];
facilities -> "about the hotel"  [color="#ff7f00", key=1, label="4/101", weight=101];
"about the hotel" -> dining  [color="#377eb8", key=0, label="1/122", weight=122];
"about the hotel" -> offers  [color="#4daf4a", key=0, label="2/103", weight=103];
"about the hotel" -> rooms  [color="#e41a1c", key=0, label="0/123", weight=123];
"about the hotel" -> rooms  [color="#ff7f00", key=1, label="4/101", weight=101];
"about the hotel" -> rooms  [color="#f781bf", key=2, label="7/96", weight=96];
dining -> offers  [color="#377eb8", key=0, label="1/122", weight=122];
dining -> offers  [color="#984ea3", key=1, label="3/102", weight=102];
dining -> offers  [color="#a65628", key=2, label="6/96", weight=96];
dining -> offers  [color="#999999", key=3, label="8/94", weight=94];
```

Save the output above to file `internal_requests.dot` and convert using the commands described above.

This produces a much cleaner looking output, where edges are colorised for assisting with reading frequency patterns between pages.



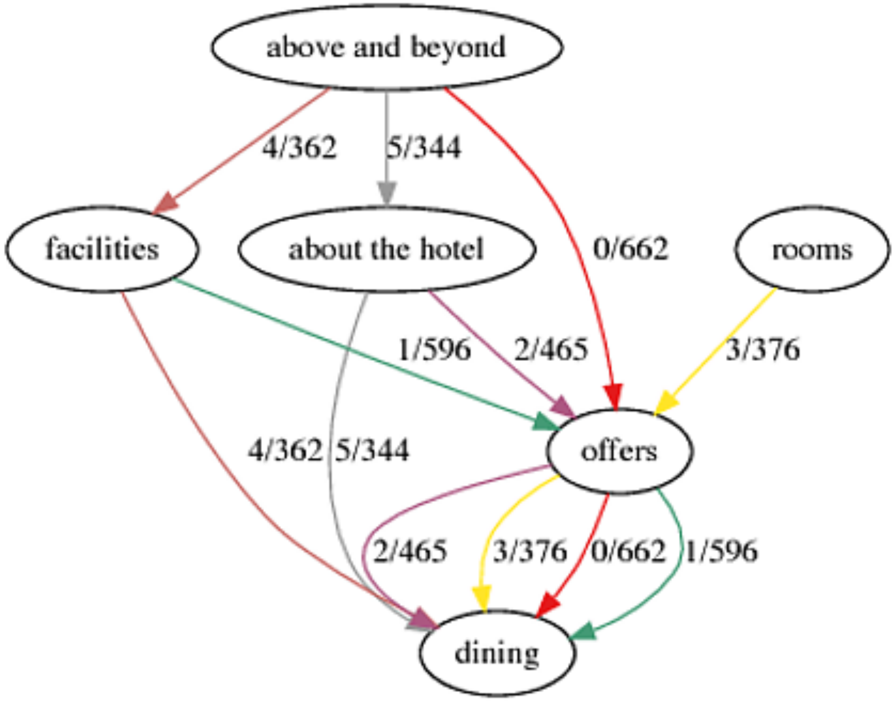
6.2.2. External Requests



```
print graph_to_pydot_string(graph_data["external_requests"][0])
```

```
digraph "" {
layout="dot";
dining;
"above and beyond";
offers;
rooms;
facilities;
"above and beyond" -> facilities  [color="#e41a1c", key=0, label="0/1823", weight=1823];
"above and beyond" -> facilities  [color="#999999", key=1, label="5/1684", weight=1684];
"above and beyond" -> offers  [color="#449b76", key=0, label="1/1760", weight=1760];
offers -> dining  [color="#449b76", key=0, label="1/1760", weight=1760];
offers -> dining  [color="#ffe529", key=1, label="3/1727", weight=1727];
rooms -> dining  [color="#c66764", key=0, label="4/1715", weight=1715];
rooms -> offers  [color="#ad5882", key=0, label="2/1732", weight=1732];
facilities -> dining  [color="#999999", key=0, label="5/1684", weight=1684];
facilities -> offers  [color="#ffe529", key=0, label="3/1727", weight=1727];
facilities -> rooms  [color="#e41a1c", key=0, label="0/1823", weight=1823];
facilities -> rooms  [color="#ad5882", key=1, label="2/1732", weight=1732];
facilities -> rooms  [color="#c66764", key=2, label="4/1715", weight=1715];
}
```

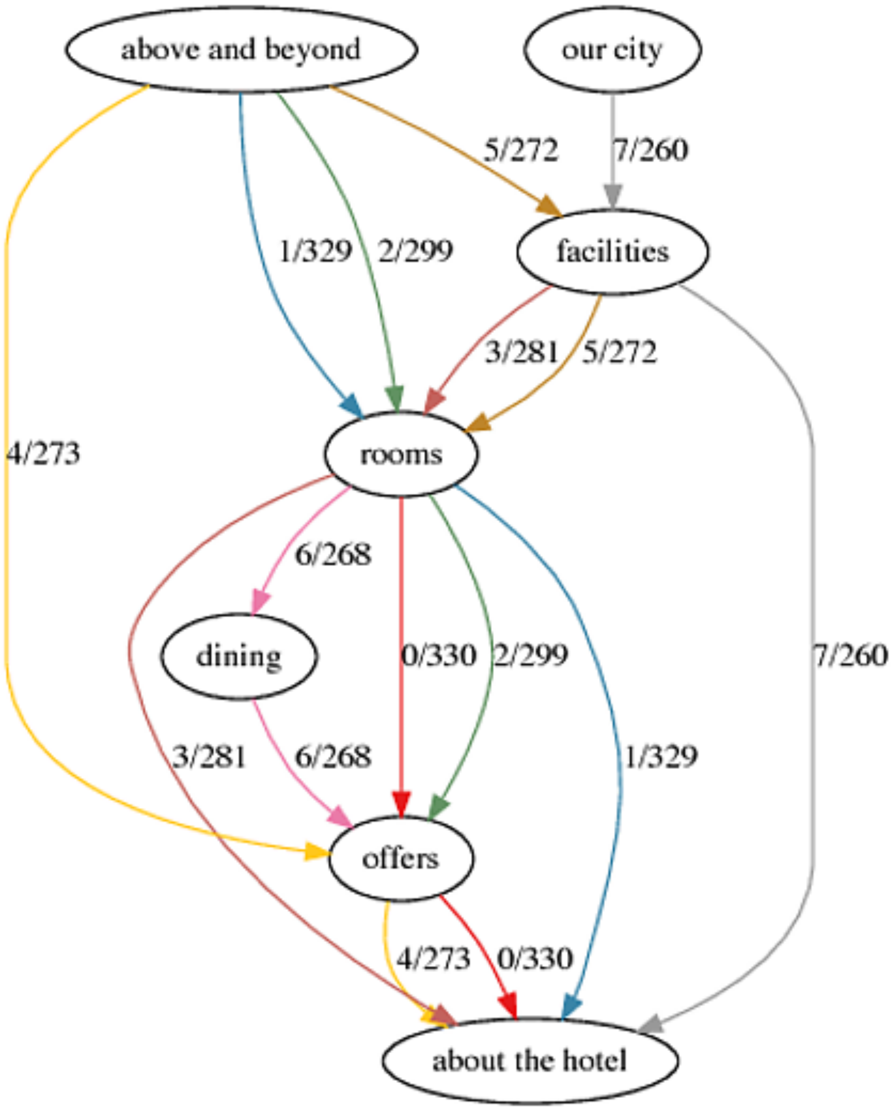
6.2.3. Hong Kong Requests



```
print graph_to_pydot_string(graph_data["hk_requests"][0])
```

```
digraph "" {
layout="dot";
dining;
"about the hotel";
facilities;
offers;
rooms;
"above and beyond";
"about the hotel" -> dining  [color="#999999", key=0, label="5/344", weight=344];
"about the hotel" -> offers  [color="#ad5882", key=0, label="2/465", weight=465];
facilities -> dining  [color="#c66764", key=0, label="4/362", weight=362];
facilities -> offers  [color="#449b76", key=0, label="1/596", weight=596];
offers -> dining  [color="#e41a1c", key=0, label="0/662", weight=662];
offers -> dining  [color="#449b76", key=1, label="1/596", weight=596];
offers -> dining  [color="#ad5882", key=2, label="2/465", weight=465];
offers -> dining  [color="#ffe529", key=3, label="3/376", weight=376];
rooms -> offers  [color="#ffe529", key=0, label="3/376", weight=376];
"above and beyond" -> facilities  [color="#c66764", key=0, label="4/362", weight=362];
"above and beyond" -> offers  [color="#e41a1c", key=0, label="0/662", weight=662];
"above and beyond" -> "about the hotel"  [color="#999999", key=0, label="5/344", weight=344];
}
```

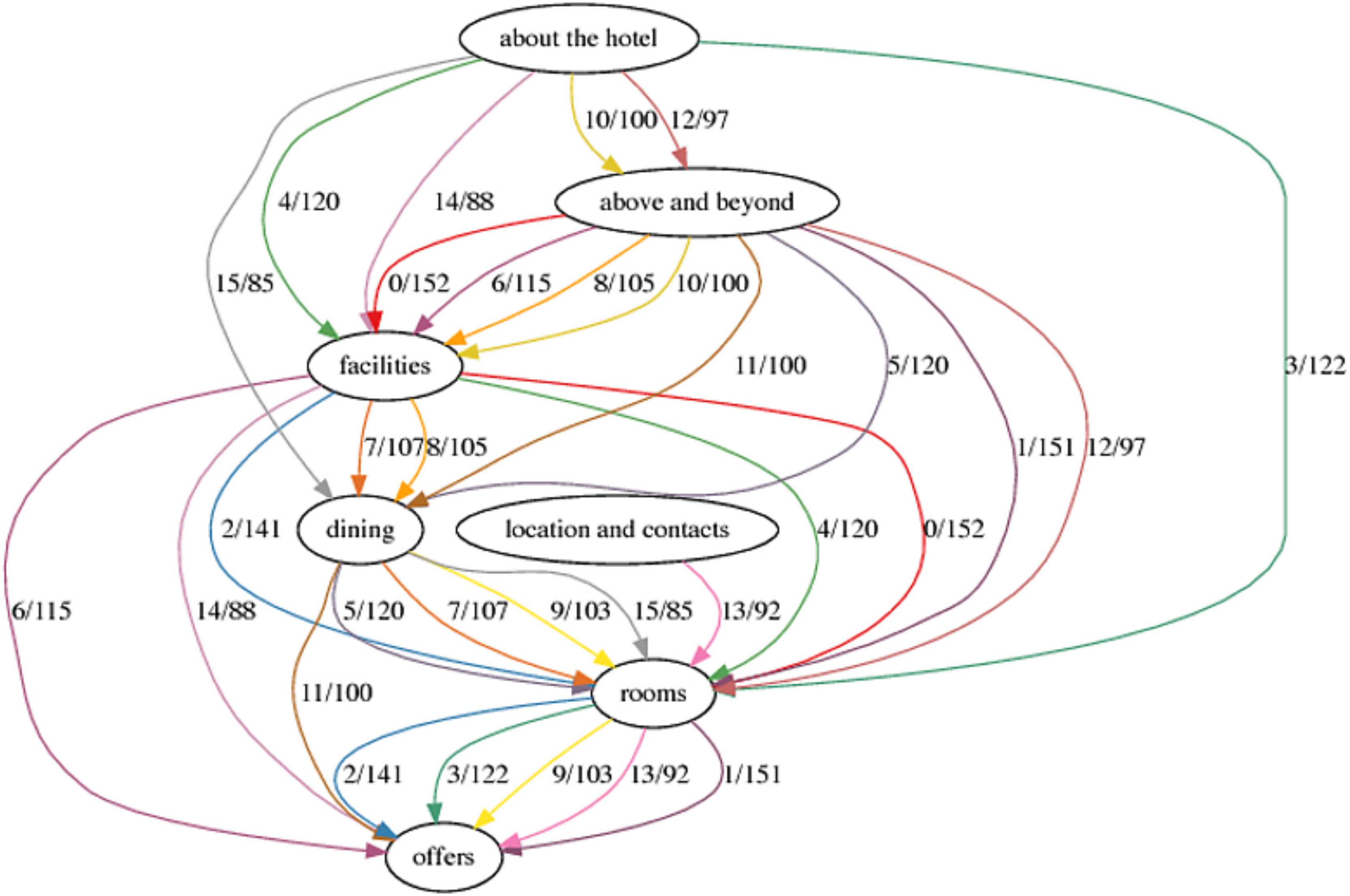
6.2.4. USA Requests



```
print graph_to_pydot_string(graph_data["us_requests"][0])
```

```
digraph "" {
layout="dot";
facilities;
"about the hotel";
dining;
offers;
rooms;
"our city";
"above and beyond";
facilities -> rooms  [color="#c4635d", key=0, label="3/281", weight=281];
facilities -> rooms  [color="#bf862b", key=1, label="5/272", weight=272];
facilities -> "about the hotel"  [color="#999999", key=0, label="7/260", weight=260];
dining -> offers  [color="#eb7ba9", key=0, label="6/268", weight=268];
offers -> "about the hotel"  [color="#e41a1c", key=0, label="0/330", weight=330];
offers -> "about the hotel"  [color="#ffc81d", key=1, label="4/273", weight=273];
rooms -> dining  [color="#eb7ba9", key=0, label="6/268", weight=268];
rooms -> offers  [color="#e41a1c", key=0, label="0/330", weight=330];
rooms -> offers  [color="#629363", key=1, label="2/299", weight=299];
rooms -> "about the hotel"  [color="#3a85a8", key=0, label="1/329", weight=329];
rooms -> "about the hotel"  [color="#c4635d", key=1, label="3/281", weight=281];
"our city" -> facilities  [color="#999999", key=0, label="7/260", weight=260];
"above and beyond" -> facilities  [color="#bf862b", key=0, label="5/272", weight=272];
"above and beyond" -> offers  [color="#ffc81d", key=0, label="4/273", weight=273];
"above and beyond" -> rooms  [color="#3a85a8", key=0, label="1/329", weight=329];
"above and beyond" -> rooms  [color="#629363", key=1, label="2/299", weight=299];
}
```

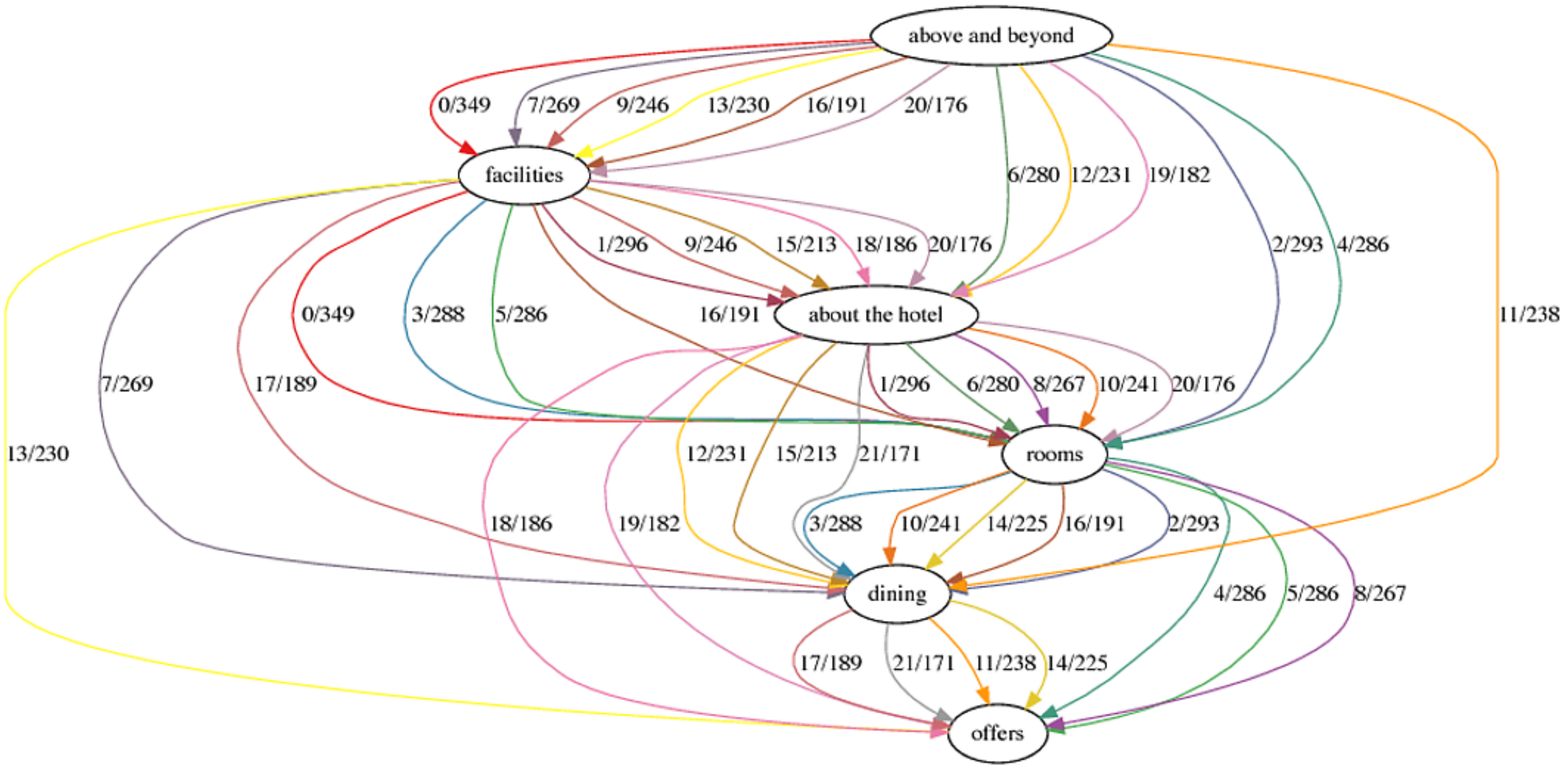
6.2.5. Australian Requests



```
print graph_to_pydot_string(graph_data["au_requests"][0])
```

```
digraph "" {
layout="dot";
facilities;
"about the hotel";
dining;
offers;
rooms;
"above and beyond";
"location and contacts";
facilities -> dining  [color="#e4722b", key=0, label="7/107", weight=107];
facilities -> dining  [color="#ffa10e", key=1, label="8/105", weight=105];
facilities -> offers  [color="#ad5882", key=0, label="6/115", weight=115];
facilities -> offers  [color="#cb8cad", key=1, label="14/88", weight=88];
facilities -> rooms  [color="#e41a1c", key=0, label="0/152", weight=152];
facilities -> rooms  [color="#3881b1", key=1, label="2/141", weight=141];
facilities -> rooms  [color="#57a256", key=2, label="4/120", weight=120];
"about the hotel" -> dining  [color="#999999", key=0, label="15/85", weight=85];
"about the hotel" -> facilities  [color="#57a256", key=0, label="4/120", weight=120];
"about the hotel" -> facilities  [color="#cb8cad", key=1, label="14/88", weight=88];
"about the hotel" -> rooms  [color="#449b76", key=0, label="3/122", weight=122];
"about the hotel" -> "above and beyond"  [color="#e1c72f", key=0, label="10/100", weight=100];
"about the hotel" -> "above and beyond"  [color="#c66764", key=1, label="12/97", weight=97];
dining -> offers  [color="#b26d29", key=0, label="11/100", weight=100];
dining -> rooms  [color="#7f6e85", key=0, label="5/120", weight=120];
dining -> rooms  [color="#e4722b", key=1, label="7/107", weight=107];
dining -> rooms  [color="#ffe529", key=2, label="9/103", weight=103];
dining -> rooms  [color="#999999", key=3, label="15/85", weight=85];
rooms -> offers  [color="#884f6f", key=0, label="1/151", weight=151];
rooms -> offers  [color="#3881b1", key=1, label="2/141", weight=141];
rooms -> offers  [color="#449b76", key=2, label="3/122", weight=122];
rooms -> offers  [color="#ffe529", key=3, label="9/103", weight=103];
rooms -> offers  [color="#f27eb5", key=4, label="13/92", weight=92];
"above and beyond" -> facilities  [color="#e41a1c", key=0, label="0/152", weight=152];
"above and beyond" -> facilities  [color="#ad5882", key=1, label="6/115", weight=115];
"above and beyond" -> facilities  [color="#ffa10e", key=2, label="8/105", weight=105];
"above and beyond" -> facilities  [color="#e1c72f", key=3, label="10/100", weight=100];
"above and beyond" -> rooms  [color="#884f6f", key=0, label="1/151", weight=151];
"above and beyond" -> rooms  [color="#c66764", key=1, label="12/97", weight=97];
"above and beyond" -> dining  [color="#7f6e85", key=0, label="5/120", weight=120];
"above and beyond" -> dining  [color="#b26d29", key=1, label="11/100", weight=100];
"location and contacts" -> rooms  [color="#f27eb5", key=0, label="13/92", weight=92];
}
```

6.2.6. PC Requests

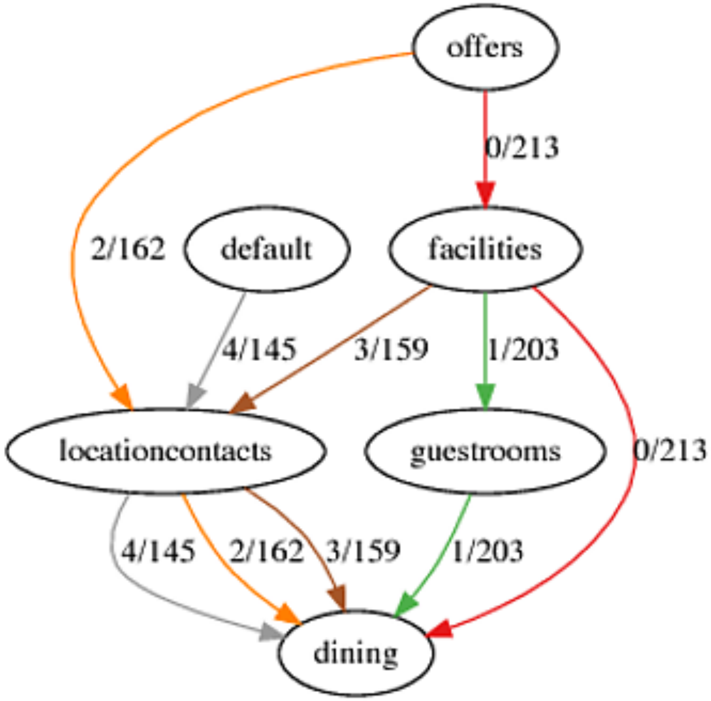


```
print graph_to_pydot_string(graph_data["pc_requests"][0])
```

```
digraph "" {
layout="dot";
facilities;
"about the hotel";
dining;
```

```
offers;
rooms;
"above and beyond";
facilities -> dining  [color="#7f6e85", key=0, label="7/269", weight=269];
facilities -> dining  [color="#cd6a70", key=1, label="17/189", weight=189];
facilities -> offers  [color="#fff931", key=0, label="13/230", weight=230];
facilities -> rooms  [color="#e41a1c", key=0, label="0/349", weight=349];
facilities -> rooms  [color="#3a85a8", key=1, label="3/288", weight=288];
facilities -> rooms  [color="#4baa54", key=2, label="5/286", weight=286];
facilities -> rooms  [color="#ae5a36", key=3, label="16/191", weight=191];
facilities -> "about the hotel"  [color="#a24057", key=0, label="1/296", weight=296];
facilities -> "about the hotel"  [color="#c4635d", key=1, label="9/246", weight=246];
facilities -> "about the hotel"  [color="#bf862b", key=2, label="15/213", weight=213];
facilities -> "about the hotel"  [color="#eb7ba9", key=3, label="18/186", weight=186];
facilities -> "about the hotel"  [color="#bd90a7", key=4, label="20/176", weight=176];
"about the hotel" -> dining  [color="#ffc81d", key=0, label="12/231", weight=231];
"about the hotel" -> dining  [color="#bf862b", key=1, label="15/213", weight=213];
"about the hotel" -> dining  [color="#999999", key=2, label="21/171", weight=171];
"about the hotel" -> offers  [color="#eb7ba9", key=0, label="18/186", weight=186];
"about the hotel" -> offers  [color="#e187b6", key=1, label="19/182", weight=182];
"about the hotel" -> rooms  [color="#a24057", key=0, label="1/296", weight=296];
"about the hotel" -> rooms  [color="#629363", key=1, label="6/280", weight=280];
"about the hotel" -> rooms  [color="#9d509b", key=2, label="8/267", weight=267];
"about the hotel" -> rooms  [color="#eb761f", key=3, label="10/241", weight=241];
"about the hotel" -> rooms  [color="#bd90a7", key=4, label="20/176", weight=176];
dining -> offers  [color="#ff970a", key=0, label="11/238", weight=238];
dining -> offers  [color="#e1c72f", key=1, label="14/225", weight=225];
dining -> offers  [color="#cd6a70", key=2, label="17/189", weight=189];
dining -> offers  [color="#999999", key=3, label="21/171", weight=171];
rooms -> dining  [color="#606693", key=0, label="2/293", weight=293];
rooms -> dining  [color="#3a85a8", key=1, label="3/288", weight=288];
rooms -> dining  [color="#eb761f", key=2, label="10/241", weight=241];
rooms -> dining  [color="#e1c72f", key=3, label="14/225", weight=225];
rooms -> dining  [color="#ae5a36", key=4, label="16/191", weight=191];
rooms -> offers  [color="#43987e", key=0, label="4/286", weight=286];
rooms -> offers  [color="#4baa54", key=1, label="5/286", weight=286];
rooms -> offers  [color="#9d509b", key=2, label="8/267", weight=267];
"above and beyond" -> dining  [color="#ff970a", key=0, label="11/238", weight=238];
"above and beyond" -> facilities  [color="#e41a1c", key=0, label="0/349", weight=349];
"above and beyond" -> facilities  [color="#7f6e85", key=1, label="7/269", weight=269];
"above and beyond" -> facilities  [color="#c4635d", key=2, label="9/246", weight=246];
"above and beyond" -> facilities  [color="#fff931", key=3, label="13/230", weight=230];
"above and beyond" -> facilities  [color="#ae5a36", key=4, label="16/191", weight=191];
"above and beyond" -> facilities  [color="#bd90a7", key=5, label="20/176", weight=176];
"above and beyond" -> rooms  [color="#606693", key=0, label="2/293", weight=293];
"above and beyond" -> rooms  [color="#43987e", key=1, label="4/286", weight=286];
"above and beyond" -> "about the hotel"  [color="#629363", key=0, label="6/280", weight=280];
"above and beyond" -> "about the hotel"  [color="#ffc81d", key=1, label="12/231", weight=231];
"above and beyond" -> "about the hotel"  [color="#e187b6", key=2, label="19/182", weight=182];
}
```

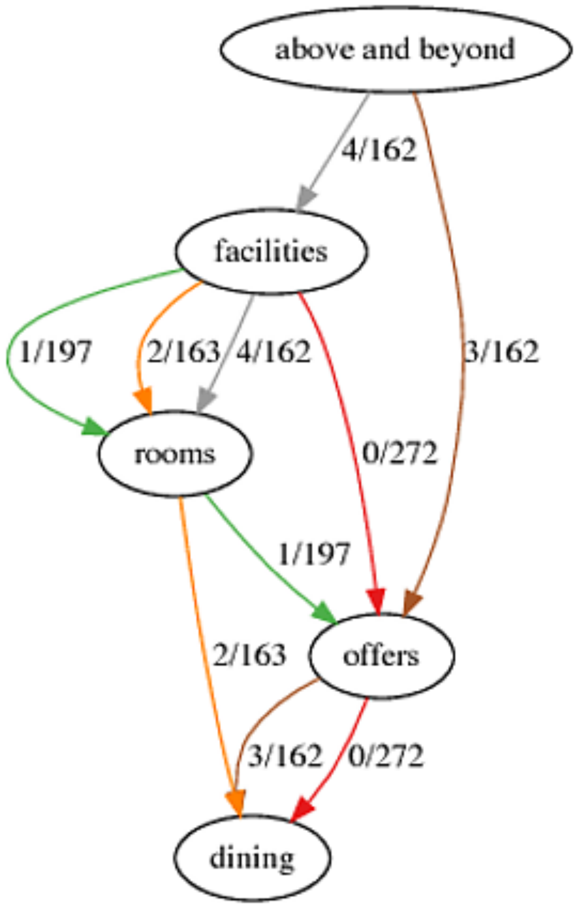
6.2.7. Smartphone Requests



```
print graph_to_pydot_string(graph_data["smartphone_requests"][0])
```

```
digraph "" {
layout="dot";
locationcontacts;
dining;
default;
facilities;
offers;
guestrooms;
locationcontacts -> dining  [color="#ff7f00", key=0, label="2/162", weight=162];
locationcontacts -> dining  [color="#a65628", key=1, label="3/159", weight=159];
locationcontacts -> dining  [color="#999999", key=2, label="4/145", weight=145];
default -> locationcontacts  [color="#999999", key=0, label="4/145", weight=145];
facilities -> dining  [color="#e41a1c", key=0, label="0/213", weight=213];
facilities -> guestrooms  [color="#4daf4a", key=0, label="1/203", weight=203];
facilities -> locationcontacts  [color="#a65628", key=0, label="3/159", weight=159];
offers -> facilities  [color="#e41a1c", key=0, label="0/213", weight=213];
offers -> locationcontacts  [color="#ff7f00", key=0, label="2/162", weight=162];
guestrooms -> dining  [color="#4daf4a", key=0, label="1/203", weight=203];
}
```

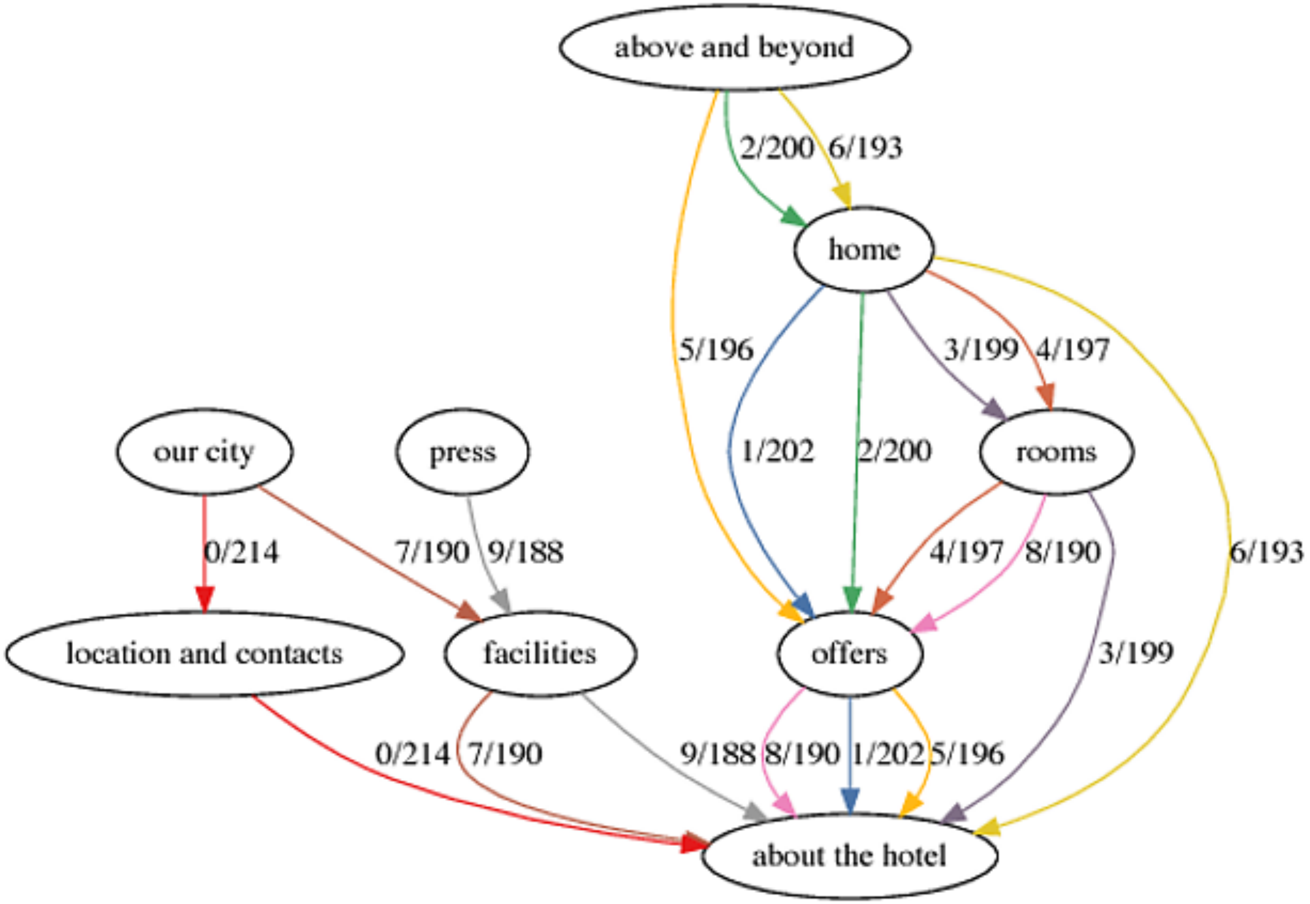
6.2.8. Tablet Requests



```
print graph_to_pydot_string(graph_data["tablet_requests"][0])
```

```
digraph "" {
layout="dot";
"above and beyond";
facilities;
offers;
rooms;
dining;
"above and beyond" -> facilities  [color="#999999", key=0, label="4/162", weight=162];
"above and beyond" -> offers  [color="#a65628", key=0, label="3/162", weight=162];
facilities -> offers  [color="#e41a1c", key=0, label="0/272", weight=272];
facilities -> rooms  [color="#4daf4a", key=0, label="1/197", weight=197];
facilities -> rooms  [color="#ff7f00", key=1, label="2/163", weight=163];
facilities -> rooms  [color="#999999", key=2, label="4/162", weight=162];
offers -> dining  [color="#e41a1c", key=0, label="0/272", weight=272];
offers -> dining  [color="#a65628", key=1, label="3/162", weight=162];
rooms -> dining  [color="#ff7f00", key=0, label="2/163", weight=163];
rooms -> offers  [color="#4daf4a", key=0, label="1/197", weight=197];
}
```

6.2.9. Bot Requests



```
print graph_to_pydot_string(graph_data["bots_requests"][0])
```

```
digraph "" {
layout="dot";
"about the hotel";
"our city";
facilities;
offers;
rooms;
"above and beyond";
press;
home;
"location and contacts";
"our city" -> facilities  [color="#b8604a", key=0, label="7/190", weight=190];
"our city" -> "location and contacts"  [color="#e41a1c", key=0, label="0/214", weight=214];
facilities -> "about the hotel"  [color="#b8604a", key=0, label="7/190", weight=190];
facilities -> "about the hotel"  [color="#999999", key=1, label="9/188", weight=188];
offers -> "about the hotel"  [color="#4a73a7", key=0, label="1/202", weight=202];
offers -> "about the hotel"  [color="#ffb817", key=1, label="5/196", weight=196];
offers -> "about the hotel"  [color="#ed84bb", key=2, label="8/190", weight=190];
rooms -> offers  [color="#d16948", key=0, label="4/197", weight=197];
rooms -> offers  [color="#ed84bb", key=1, label="8/190", weight=190];
rooms -> "about the hotel"  [color="#7f6e85", key=0, label="3/199", weight=199];
"above and beyond" -> home  [color="#48a462", key=0, label="2/200", weight=200];
"above and beyond" -> home  [color="#e1c72f", key=1, label="6/193", weight=193];
"above and beyond" -> offers  [color="#ffb817", key=0, label="5/196", weight=196];
press -> facilities  [color="#999999", key=0, label="9/188", weight=188];
home -> offers  [color="#4a73a7", key=0, label="1/202", weight=202];
home -> offers  [color="#48a462", key=1, label="2/200", weight=200];
home -> rooms  [color="#7f6e85", key=0, label="3/199", weight=199];
home -> rooms  [color="#d16948", key=1, label="4/197", weight=197];
home -> "about the hotel"  [color="#e1c72f", key=0, label="6/193", weight=193];
"location and contacts" -> "about the hotel"  [color="#e41a1c", key=0, label="0/214", weight=214];
}
```

7. CSV Output

We can provide a reference table to support the diagram as a table and import this into our LaTeX report:

```
print "internal_requests.csv"
print graph_data["internal_requests"][1]
print
print "external_requests.csv"
print graph_data["external_requests"][1]
print
print "hk_requests.csv"
print graph_data["hk_requests"][1]
print
print "us_requests.csv"
print graph_data["us_requests"][1]
print
print "au_requests.csv"
print graph_data["au_requests"][1]
print
print "pc_requests.csv"
print graph_data["pc_requests"][1]
print
print "smartphone_requests.csv"
print graph_data["smartphone_requests"][1]
print
print "tablet_requests.csv"
print graph_data["tablet_requests"][1]
print
print "bots_requests.csv"
print graph_data["bots_requests"][1]
```

```
internal_requests.csv
Sequence,From,To,Frequency
0,about the hotel,rooms,123
0,rooms,offers,123
1,about the hotel,dining,122
1,dining,offers,122
2,facilities,about the hotel,103
```

```
2,about the hotel,offers,103
3,rooms,dining,102
3,dining,offers,102
4,facilities,about the hotel,101
4,about the hotel,rooms,101
5,facilities,rooms,99
5,rooms,offers,99
6,facilities,dining,96
6,dining,offers,96
7,about the hotel,rooms,96
7,rooms,dining,96
8,above and beyond,dining,94
8,dining,offers,94

external_requests.csv
Sequence,From,To,Frequency
0,above and beyond,facilities,1823
0,facilities,rooms,1823
1,above and beyond,offers,1760
1,offers,dining,1760
2,facilities,rooms,1732
2,rooms,offers,1732
3,facilities,offers,1727
3,offers,dining,1727
4,facilities,rooms,1715
4,rooms,dining,1715
5,above and beyond,facilities,1684
5,facilities,dining,1684

hk_requests.csv
Sequence,From,To,Frequency
0,above and beyond,offers,662
0,offers,dining,662
1,facilities,offers,596
1,offers,dining,596
```

```
2,about the hotel,offers,465
2,offers,dining,465
3,rooms,offers,376
3,offers,dining,376
4,above and beyond,facilities,362
4,facilities,dining,362
5,above and beyond,about the hotel,344
5,about the hotel,dining,344

us_requests.csv
Sequence,From,To,Frequency
0,rooms,offers,330
0,offers,about the hotel,330
1,above and beyond,rooms,329
1,rooms,about the hotel,329
2,above and beyond,rooms,299
2,rooms,offers,299
3,facilities,rooms,281
3,rooms,about the hotel,281
4,above and beyond,offers,273
4,offers,about the hotel,273
5,above and beyond,facilities,272
5,facilities,rooms,272
6,rooms,dining,268
6,dining,offers,268
7,our city,facilities,260
7,facilities,about the hotel,260

au_requests.csv
Sequence,From,To,Frequency
0,above and beyond,facilities,152
0,facilities,rooms,152
1,above and beyond,rooms,151
1,rooms,offers,151
2,facilities,rooms,141
```

```
2,rooms,offers,141
3,about the hotel,rooms,122
3,rooms,offers,122
4,about the hotel,facilities,120
4,facilities,rooms,120
5,above and beyond,dining,120
5,dining,rooms,120
6,above and beyond,facilities,115
6,facilities,offers,115
7,facilities,dining,107
7,dining,rooms,107
8,above and beyond,facilities,105
8,facilities,dining,105
9,dining,rooms,103
9,rooms,offers,103
10,about the hotel,above and beyond,100
10,above and beyond,facilities,100
11,above and beyond,dining,100
11,dining,offers,100
12,about the hotel,above and beyond,97
12,above and beyond,rooms,97
13,location and contacts,rooms,92
13,rooms,offers,92
14,about the hotel,facilities,88
14,facilities,offers,88
15,about the hotel,dining,85
15,dining,rooms,85
```

pc_requests.csv

```
Sequence,From,To,Frequency
0,above and beyond,facilities,349
0,facilities,rooms,349
1,facilities,about the hotel,296
1,about the hotel,rooms,296
2,above and beyond,rooms,293
```

```
2,rooms,dining,293
3,facilities,rooms,288
3,rooms,dining,288
4,above and beyond,rooms,286
4,rooms,offers,286
5,facilities,rooms,286
5,rooms,offers,286
6,above and beyond,about the hotel,280
6,about the hotel,rooms,280
7,above and beyond,facilities,269
7,facilities,dining,269
8,about the hotel,rooms,267
8,rooms,offers,267
9,above and beyond,facilities,246
9,facilities,about the hotel,246
10,about the hotel,rooms,241
10,rooms,dining,241
11,above and beyond,dining,238
11,dining,offers,238
12,above and beyond,about the hotel,231
12,about the hotel,dining,231
13,above and beyond,facilities,230
13,facilities,offers,230
14,rooms,dining,225
14,dining,offers,225
15,facilities,about the hotel,213
15,about the hotel,dining,213
16,above and beyond,facilities,191
16,facilities,rooms,191
16,rooms,dining,191
17,facilities,dining,189
17,dining,offers,189
18,facilities,about the hotel,186
18,about the hotel,offers,186
19,above and beyond,about the hotel,182
```

```
19,about the hotel,offers,182
20,above and beyond,facilities,176
20,facilities,about the hotel,176
20,about the hotel,rooms,176
21,about the hotel,dining,171
21,dining,offers,171
```

smartphone_requests.csv

```
Sequence,From,To,Frequency
0,offers,facilities,213
0,facilities,dining,213
1,facilities,guestrooms,203
1,guestrooms,dining,203
2,offers,locationcontacts,162
2,locationcontacts,dining,162
3,facilities,locationcontacts,159
3,locationcontacts,dining,159
4,default,locationcontacts,145
4,locationcontacts,dining,145
```

tablet_requests.csv

```
Sequence,From,To,Frequency
0,facilities,offers,272
0,offers,dining,272
1,facilities,rooms,197
1,rooms,offers,197
2,facilities,rooms,163
2,rooms,dining,163
3,above and beyond,offers,162
3,offers,dining,162
4,above and beyond,facilities,162
4,facilities,rooms,162
```

bots_requests.csv

```
Sequence,From,To,Frequency
```

```
0,our city,location and contacts,214
0,location and contacts,about the hotel,214
1,home,offers,202
1,offers,about the hotel,202
2,above and beyond,home,200
2,home,offers,200
3,home,rooms,199
3,rooms,about the hotel,199
4,home,rooms,197
4,rooms,offers,197
5,above and beyond,offers,196
5,offers,about the hotel,196
6,above and beyond,home,193
6,home,about the hotel,193
7,our city,facilities,190
7,facilities,about the hotel,190
8,rooms,offers,190
8,offers,about the hotel,190
9,press,facilities,188
9,facilities,about the hotel,188
```

```
internal_requests.dot
digraph "" {
layout="dot";
facilities;
"about the hotel";
dining;
offers;
rooms;
"above and beyond";
facilities -> dining  [color="#a65628", key=0, label="6/96", weight=96];
facilities -> rooms  [color="#ffff33", key=0, label="5/99", weight=99];
facilities -> "about the hotel"  [color="#4daf4a", key=0, label="2/103", weight=103];
facilities -> "about the hotel"  [color="#ff7f00", key=1, label="4/101", weight=101];
"about the hotel" -> dining  [color="#377eb8", key=0, label="1/122", weight=122];
"about the hotel" -> offers  [color="#4daf4a", key=0, label="2/103", weight=103];
"about the hotel" -> rooms  [color="#e41a1c", key=0, label="0/123", weight=123];
"about the hotel" -> rooms  [color="#ff7f00", key=1, label="4/101", weight=101];
"about the hotel" -> rooms  [color="#f781bf", key=2, label="7/96", weight=96];
dining -> offers  [color="#377eb8", key=0, label="1/122", weight=122];
dining -> offers  [color="#984ea3", key=1, label="3/102", weight=102];
dining -> offers  [color="#a65628", key=2, label="6/96", weight=96];
dining -> offers  [color="#999999", key=3, label="8/94", weight=94];
rooms -> dining  [color="#984ea3", key=0, label="3/102", weight=102];
rooms -> dining  [color="#f781bf", key=1, label="7/96", weight=96];
rooms -> offers  [color="#e41a1c", key=0, label="0/123", weight=123];
rooms -> offers  [color="#ffff33", key=1, label="5/99", weight=99];
"above and beyond" -> dining  [color="#999999", key=0, label="8/94", weight=94];
}
```

external_requests.dot

```
digraph "" {
layout="dot";
dining;
"above and beyond";
offers;
rooms;
facilities;
"above and beyond" -> facilities  [color="#e41a1c", key=0, label="0/1823", weight=1823];
"above and beyond" -> facilities  [color="#999999", key=1, label="5/1684", weight=1684];
"above and beyond" -> offers  [color="#449b76", key=0, label="1/1760", weight=1760];
offers -> dining  [color="#449b76", key=0, label="1/1760", weight=1760];
offers -> dining  [color="#ffe529", key=1, label="3/1727", weight=1727];
rooms -> dining  [color="#c66764", key=0, label="4/1715", weight=1715];
rooms -> offers  [color="#ad5882", key=0, label="2/1732", weight=1732];
facilities -> dining  [color="#999999", key=0, label="5/1684", weight=1684];
facilities -> offers  [color="#ffe529", key=0, label="3/1727", weight=1727];
facilities -> rooms  [color="#e41a1c", key=0, label="0/1823", weight=1823];
facilities -> rooms  [color="#ad5882", key=1, label="2/1732", weight=1732];
facilities -> rooms  [color="#c66764", key=2, label="4/1715", weight=1715];
}


hk_requests.dot
digraph "" {
layout="dot";
dining;
"about the hotel";
facilities;
offers;
rooms;
"above and beyond";
"about the hotel" -> dining  [color="#999999", key=0, label="5/344", weight=344];
"about the hotel" -> offers  [color="#ad5882", key=0, label="2/465", weight=465];
facilities -> dining  [color="#c66764", key=0, label="4/362", weight=362];
facilities -> offers  [color="#449b76", key=0, label="1/596", weight=596];
offers -> dining  [color="#e41a1c", key=0, label="0/662", weight=662];
offers -> dining  [color="#449b76", key=1, label="1/596", weight=596];
offers -> dining  [color="#ad5882", key=2, label="2/465", weight=465];
offers -> dining  [color="#ffe529", key=3, label="3/376", weight=376];
rooms -> offers  [color="#ffe529", key=0, label="3/376", weight=376];
"above and beyond" -> facilities  [color="#c66764", key=0, label="4/362", weight=362];
"above and beyond" -> offers  [color="#e41a1c", key=0, label="0/662", weight=662];
"above and beyond" -> "about the hotel"  [color="#999999", key=0, label="5/344", weight=344];
}


us_requests.dot
digraph "" {
layout="dot";
facilities;
"about the hotel";
dining;
offers;
```

```
rooms;
"our city";
"above and beyond";
facilities -> rooms  [color="#c4635d", key=0, label="3/281", weight=281];
facilities -> rooms  [color="#bf862b", key=1, label="5/272", weight=272];
facilities -> "about the hotel"  [color="#999999", key=0, label="7/260", weight=260];
dining -> offers  [color="#eb7ba9", key=0, label="6/268", weight=268];
offers -> "about the hotel"  [color="#e41a1c", key=0, label="0/330", weight=330];
offers -> "about the hotel"  [color="#ffc81d", key=1, label="4/273", weight=273];
rooms -> dining  [color="#eb7ba9", key=0, label="6/268", weight=268];
rooms -> offers  [color="#e41a1c", key=0, label="0/330", weight=330];
rooms -> offers  [color="#629363", key=1, label="2/299", weight=299];
rooms -> "about the hotel"  [color="#3a85a8", key=0, label="1/329", weight=329];
rooms -> "about the hotel"  [color="#c4635d", key=1, label="3/281", weight=281];
"our city" -> facilities  [color="#999999", key=0, label="7/260", weight=260];
"above and beyond" -> facilities  [color="#bf862b", key=0, label="5/272", weight=272];
"above and beyond" -> offers  [color="#ffc81d", key=0, label="4/273", weight=273];
"above and beyond" -> rooms  [color="#3a85a8", key=0, label="1/329", weight=329];
"above and beyond" -> rooms  [color="#629363", key=1, label="2/299", weight=299];
}
```

au_requests.dot

```
digraph "" {
layout="dot";
facilities;
"about the hotel";
dining;
offers;
rooms;
"above and beyond";
"location and contacts";
facilities -> dining  [color="#e4722b", key=0, label="7/107", weight=107];
facilities -> dining  [color="#ffa10e", key=1, label="8/105", weight=105];
facilities -> offers  [color="#ad5882", key=0, label="6/115", weight=115];
facilities -> offers  [color="#cb8cad", key=1, label="14/88", weight=88];
facilities -> rooms  [color="#e41a1c", key=0, label="0/152", weight=152];
facilities -> rooms  [color="#3881b1", key=1, label="2/141", weight=141];
facilities -> rooms  [color="#57a256", key=2, label="4/120", weight=120];
"about the hotel" -> dining  [color="#999999", key=0, label="15/85", weight=85];
"about the hotel" -> facilities  [color="#57a256", key=0, label="4/120", weight=120];
"about the hotel" -> facilities  [color="#cb8cad", key=1, label="14/88", weight=88];
"about the hotel" -> rooms  [color="#449b76", key=0, label="3/122", weight=122];
"about the hotel" -> "above and beyond"  [color="#e1c72f", key=0, label="10/100", weight=100];
"about the hotel" -> "above and beyond"  [color="#c66764", key=1, label="12/97", weight=97];
dining -> offers  [color="#b26d29", key=0, label="11/100", weight=100];
dining -> rooms  [color="#7f6e85", key=0, label="5/120", weight=120];
dining -> rooms  [color="#e4722b", key=1, label="7/107", weight=107];
dining -> rooms  [color="#ffe529", key=2, label="9/103", weight=103];
dining -> rooms  [color="#999999", key=3, label="15/85", weight=85];
rooms -> offers  [color="#884f6f", key=0, label="1/151", weight=151];
rooms -> offers  [color="#3881b1", key=1, label="2/141", weight=141];
rooms -> offers  [color="#449b76", key=2, label="3/122", weight=122];
rooms -> offers  [color="#ffe529", key=3, label="9/103", weight=103];
rooms -> offers  [color="#f27eb5", key=4, label="13/92", weight=92];
"above and beyond" -> facilities  [color="#e41a1c", key=0, label="0/152", weight=152];
"above and beyond" -> facilities  [color="#ad5882", key=1, label="6/115", weight=115];
"above and beyond" -> facilities  [color="#ffa10e", key=2, label="8/105", weight=105];
"above and beyond" -> facilities  [color="#e1c72f", key=3, label="10/100", weight=100];
"above and beyond" -> rooms  [color="#884f6f", key=0, label="1/151", weight=151];
"above and beyond" -> rooms  [color="#c66764", key=1, label="12/97", weight=97];
"above and beyond" -> dining  [color="#7f6e85", key=0, label="5/120", weight=120];
"above and beyond" -> dining  [color="#b26d29", key=1, label="11/100", weight=100];
"location and contacts" -> rooms  [color="#f27eb5", key=0, label="13/92", weight=92];
}


pc_requests.dot
digraph "" {
layout="dot";
```

```
facilities;
"about the hotel";
dining;
offers;
rooms;
"above and beyond";
facilities -> dining  [color="#7f6e85", key=0, label="7/269", weight=269];
facilities -> dining  [color="#cd6a70", key=1, label="17/189", weight=189];
facilities -> offers  [color="#fff931", key=0, label="13/230", weight=230];
facilities -> rooms  [color="#e41a1c", key=0, label="0/349", weight=349];
facilities -> rooms  [color="#3a85a8", key=1, label="3/288", weight=288];
facilities -> rooms  [color="#4baa54", key=2, label="5/286", weight=286];
facilities -> rooms  [color="#ae5a36", key=3, label="16/191", weight=191];
facilities -> "about the hotel"  [color="#a24057", key=0, label="1/296", weight=296];
facilities -> "about the hotel"  [color="#c4635d", key=1, label="9/246", weight=246];
facilities -> "about the hotel"  [color="#bf862b", key=2, label="15/213", weight=213];
facilities -> "about the hotel"  [color="#eb7ba9", key=3, label="18/186", weight=186];
facilities -> "about the hotel"  [color="#bd90a7", key=4, label="20/176", weight=176];
"about the hotel" -> dining  [color="#ffc81d", key=0, label="12/231", weight=231];
"about the hotel" -> dining  [color="#bf862b", key=1, label="15/213", weight=213];
"about the hotel" -> dining  [color="#999999", key=2, label="21/171", weight=171];
"about the hotel" -> offers  [color="#eb7ba9", key=0, label="18/186", weight=186];
"about the hotel" -> offers  [color="#e187b6", key=1, label="19/182", weight=182];
"about the hotel" -> rooms  [color="#a24057", key=0, label="1/296", weight=296];
"about the hotel" -> rooms  [color="#629363", key=1, label="6/280", weight=280];
"about the hotel" -> rooms  [color="#9d509b", key=2, label="8/267", weight=267];
"about the hotel" -> rooms  [color="#eb761f", key=3, label="10/241", weight=241];
"about the hotel" -> rooms  [color="#bd90a7", key=4, label="20/176", weight=176];
dining -> offers  [color="#ff970a", key=0, label="11/238", weight=238];
dining -> offers  [color="#e1c72f", key=1, label="14/225", weight=225];
dining -> offers  [color="#cd6a70", key=2, label="17/189", weight=189];
dining -> offers  [color="#999999", key=3, label="21/171", weight=171];
rooms -> dining  [color="#606693", key=0, label="2/293", weight=293];
rooms -> dining  [color="#3a85a8", key=1, label="3/288", weight=288];
rooms -> dining  [color="#eb761f", key=2, label="10/241", weight=241];
rooms -> dining  [color="#e1c72f", key=3, label="14/225", weight=225];
rooms -> dining  [color="#ae5a36", key=4, label="16/191", weight=191];
rooms -> offers  [color="#43987e", key=0, label="4/286", weight=286];
rooms -> offers  [color="#4baa54", key=1, label="5/286", weight=286];
rooms -> offers  [color="#9d509b", key=2, label="8/267", weight=267];
"above and beyond" -> dining  [color="#ff970a", key=0, label="11/238", weight=238];
"above and beyond" -> facilities  [color="#e41a1c", key=0, label="0/349", weight=349];
"above and beyond" -> facilities  [color="#7f6e85", key=1, label="7/269", weight=269];
"above and beyond" -> facilities  [color="#c4635d", key=2, label="9/246", weight=246];
"above and beyond" -> facilities  [color="#fff931", key=3, label="13/230", weight=230];
"above and beyond" -> facilities  [color="#ae5a36", key=4, label="16/191", weight=191];
"above and beyond" -> facilities  [color="#bd90a7", key=5, label="20/176", weight=176];
"above and beyond" -> rooms  [color="#606693", key=0, label="2/293", weight=293];
"above and beyond" -> rooms  [color="#43987e", key=1, label="4/286", weight=286];
"above and beyond" -> "about the hotel"  [color="#629363", key=0, label="6/280", weight=280];
"above and beyond" -> "about the hotel"  [color="#ffc81d", key=1, label="12/231", weight=231];
"above and beyond" -> "about the hotel"  [color="#e187b6", key=2, label="19/182", weight=182];
}
```

smartphone_requests.dot

```
digraph "" {
layout="dot";
locationcontacts;
dining;
default;
facilities;
offers;
guestrooms;
locationcontacts -> dining  [color="#ff7f00", key=0, label="2/162", weight=162];
locationcontacts -> dining  [color="#a65628", key=1, label="3/159", weight=159];
locationcontacts -> dining  [color="#999999", key=2, label="4/145", weight=145];
default -> locationcontacts  [color="#999999", key=0, label="4/145", weight=145];
facilities -> dining  [color="#e41a1c", key=0, label="0/213", weight=213];
facilities -> guestrooms  [color="#4daf4a", key=0, label="1/203", weight=203];
facilities -> locationcontacts  [color="#a65628", key=0, label="3/159", weight=159];
offers -> facilities  [color="#e41a1c", key=0, label="0/213", weight=213];
offers -> locationcontacts  [color="#ff7f00", key=0, label="2/162", weight=162];
guestrooms -> dining  [color="#4daf4a", key=0, label="1/203", weight=203];
}
```

tablet_requests.dot

```
digraph "" {
layout="dot";
"above and beyond";
facilities;
offers;
rooms;
dining;
"above and beyond" -> facilities  [color="#999999", key=0, label="4/162", weight=162];
"above and beyond" -> offers  [color="#a65628", key=0, label="3/162", weight=162];
facilities -> offers  [color="#e41a1c", key=0, label="0/272", weight=272];
facilities -> rooms  [color="#4daf4a", key=0, label="1/197", weight=197];
facilities -> rooms  [color="#ff7f00", key=1, label="2/163", weight=163];
facilities -> rooms  [color="#999999", key=2, label="4/162", weight=162];
offers -> dining  [color="#e41a1c", key=0, label="0/272", weight=272];
offers -> dining  [color="#a65628", key=1, label="3/162", weight=162];
rooms -> dining  [color="#ff7f00", key=0, label="2/163", weight=163];
rooms -> offers  [color="#4daf4a", key=0, label="1/197", weight=197];
}
```

bots_requests.dot

```
digraph "" {
layout="dot";
"about the hotel";
"our city";
facilities;
offers;
rooms;
"above and beyond";
press;
home;
"location and contacts";
"our city" -> facilities  [color="#b8604a", key=0, label="7/190", weight=190];
"our city" -> "location and contacts"  [color="#e41a1c", key=0, label="0/214", weight=214];
facilities -> "about the hotel"  [color="#b8604a", key=0, label="7/190", weight=190];
facilities -> "about the hotel"  [color="#999999", key=1, label="9/188", weight=188];
offers -> "about the hotel"  [color="#4a73a7", key=0, label="1/202", weight=202];
offers -> "about the hotel"  [color="#ffb817", key=1, label="5/196", weight=196];
offers -> "about the hotel"  [color="#ed84bb", key=2, label="8/190", weight=190];
rooms -> offers  [color="#d16948", key=0, label="4/197", weight=197];
rooms -> offers  [color="#ed84bb", key=1, label="8/190", weight=190];
rooms -> "about the hotel"  [color="#7f6e85", key=0, label="3/199", weight=199];
"above and beyond" -> home  [color="#48a462", key=0, label="2/200", weight=200];
"above and beyond" -> home  [color="#e1c72f", key=1, label="6/193", weight=193];
"above and beyond" -> offers  [color="#ffb817", key=0, label="5/196", weight=196];
press -> facilities  [color="#999999", key=0, label="9/188", weight=188];
home -> offers  [color="#4a73a7", key=0, label="1/202", weight=202];
home -> offers  [color="#48a462", key=1, label="2/200", weight=200];
home -> rooms  [color="#7f6e85", key=0, label="3/199", weight=199];
home -> rooms  [color="#d16948", key=1, label="4/197", weight=197];
home -> "about the hotel"  [color="#e1c72f", key=0, label="6/193", weight=193];
"location and contacts" -> "about the hotel"  [color="#e41a1c", key=0, label="0/214", weight=214];
}
```