notebook

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1 Projet Traitement et Données Large Échelle

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‼ Attention : Notebook très long (environ 45 minutes d'exécution)

Cela s'explique par la nature du benchmark :

- Chaque opération (Create, Read, Update, Delete) est répétée 5 fois pour assurer la fiabilité des résultats.
- À chaque Update ou Delete (et même Select pour rester cohérent), il est nécessaire de drop la table et l'index, puis de les recréer.
- Nous avons testé sur différents volumes de données : faible, 8k, et 30k, pour observer les variations de performances.
- Nous avons évalué les performances avec 1, 2, et 5 réplicas.
- Enfin, les tests ont été réalisés avec et sans index.

1.1 Exécution des scripts d'installation

Nous avons initialement exploré la possibilité d'exécuter nos scripts sur Google Colab afin de faciliter l'exécution sans que vous ayez à configurer quoi que ce soit sur votre machine locale. Cependant, Colab présente certaines limitations, notamment l'incapacité de gérer plusieurs réplicas sets, car il ne permet de travailler qu'avec un seul environnement d'exécution.

Pour pouvoir simuler plusieurs réplicas sets dans notre projet, nous avons besoin de plusieurs nœuds, ce qui n'est pas possible sur Colab. Nous avons également essayé d'utiliser des solutions gratuites comme Datastax (ou une autre plateforme similaire), mais ces services ne permettaient pas de configurer correctement les réplicas sets, ce qui limitait la flexibilité nécessaire à notre projet.

En conséquence, nous avons opté pour une autre solution : créer des fichiers de configuration et utiliser un Jupyter Notebook. Cette approche permet de travailler de manière plus flexible tout en maintenant un contrôle total sur les paramètres des réplicas sets.

‼ Une autre remarque importante : le projet a été testé avec Python 3.11, car Python 3.12 a introduit quelques incompatibilités qui ont causé des bugs. Il est donc recommandé d'utiliser Python 3.11 pour éviter ces problèmes. ‼

‼ Toutes les instructions se trouvent dans `install_cassandra_linux.md` ‼

1.1.1 Choix de la base de données : MySQL vs SQLite

Initialement, nous avons choisi MySQL pour ses fonctionnalités robustes et sa capacité à gérer de grandes bases de données. Cependant, son intégration à Google Colab a posé plusieurs problèmes :

- Installation et configuration du serveur complexes dans un environnement éphémère.
- Difficulté à maintenir un serveur actif sur Colab, entraînant des arrêts inattendus.
- Configuration complexe pour établir des connexions sécurisées à distance.

Pour simplifier, nous avons opté pour SQLite, une solution mieux adaptée à nos besoins :

- Sans serveur : Pas de configuration complexe, tout fonctionne directement via des fichiers.
- Compatibilité native : Intégré à Python, fonctionne localement et sur le cloud.

SQLite s'est révélé être une solution efficace, ce qui nous a incités à le conserver lors de notre transition vers Jupyter Notebook.

2 Comparaison de Performances entre Systèmes Relationnels et NoSQL : Étude de Cas avec le Catalogue Netflix

Dans ce projet, nous comparons les performances entre un système de base de données relationnel (SQLite) et un système NoSQL (Cassandra), en utilisant le **catalogue Netflix** comme jeu de données.
Ce dataset, disponible en Open Data, offre une structure réaliste et adaptée pour explorer les différences entre ces deux approches de gestion de données.
L'objectif principal est d'évaluer les performances des opérations d'insertion, de sélection, de mise à jour et de suppression, tout en explorant les particularités du système NoSQL choisi.

2.0.1 Jeu de données

Le jeu de données utilisé contient des informations sur les films et séries disponibles sur Netflix, avec les attributs suivants : - `show_id` : Identifiant unique pour chaque émission ou film - `type` - `title` - `director` - `cast` - `country` - `date_added` - `release_year` - `rating` - `duration` - `listed_in` - `description`

2.0.2 Schéma de données

```
CREATE TABLE IF NOT EXISTS shows (
    show_id INT PRIMARY KEY,
    title TEXT,
    type TEXT,
    director TEXT,
    cast TEXT,
    country TEXT,
    date_added TEXT,
    release_year INT,
    rating TEXT,
    duration TEXT,
    listed_in TEXT,
```

```
    description TEXT
);
```

2.1 Fonctionnement de Cassandra

Apache Cassandra est un système NoSQL conçu pour gérer de grandes quantités de données de manière distribuée, garantissant une haute disponibilité et une tolérance aux pannes grâce à son modèle décentralisé et évolutif.

2.1.1 Modèle de données de Cassandra :

Le modèle de données de Cassandra repose sur quelques concepts clés qui diffèrent des systèmes relationnels traditionnels.

- **Keyspace** :
  Un Keyspace dans Cassandra est l'équivalent d'une base de données dans les systèmes relationnels. Il sert à regrouper des tables (ou Column Families) et définit la stratégie de réplication des données. Par exemple, il spécifie le nombre de répliques à conserver pour chaque donnée afin d'assurer une haute disponibilité et une tolérance aux pannes. La réplication des données dans Cassandra suit des stratégies comme "SimpleStrategy" (réplication sur tous les nœuds) ou "NetworkTopologyStrategy" (réplication sur des nœuds répartis sur plusieurs centres de données). Dans ce projet, nous n'explorerons que la stratégie "SimpleStrategy".
- **Column Family** :
  Une Column Family dans Cassandra est équivalente à une table relationnelle, mais avec une flexibilité plus grande. Chaque Column Family contient plusieurs colonnes, et contrairement aux bases de données relationnelles, les colonnes n'ont pas besoin d'être définies à l'avance. Elles peuvent être ajoutées dynamiquement au fil du temps, ce qui permet d'évoluer facilement sans migrations complexes.
- **Key (Clé primaire)** :
  Chaque ligne dans une Column Family est identifiée par une clé unique. Cette clé est utilisée pour partitionner et localiser les données efficacement. Elle peut être composée d'un seul champ (clé primaire simple) ou de plusieurs champs (clé primaire composée).
- **Colonnes** :
  Les données dans Cassandra sont stockées sous forme de colonnes. Chaque colonne a trois composants essentiels :
  - Nom : Le nom de la colonne (par exemple, title, release_year).
  - Valeur : La donnée proprement dite (par exemple, "Inception", "2010").
  - Timestamp : Le timestamp associé à la colonne, qui permet de gérer les versions des données et de résoudre les conflits de réplication, ce qui est essentiel dans un système distribué. Il permet de savoir quelle version d'une colonne est la plus récente.
    Ces colonnes sont indépendantes les unes des autres. Cela signifie qu'elles peuvent être insérées, mises à jour ou supprimées sans impacter les autres colonnes dans la même ligne.
- **Super Colonnes** :
  Les Super Colonnes sont une structure plus avancée dans Cassandra. Elles permettent de

regrouper plusieurs colonnes sous un même nom de “super colonne”. Cela permet de créer des structures hiérarchiques ou imbriquées dans les données, où une super colonne peut contenir plusieurs colonnes. Ce mécanisme est utile pour des cas complexes, mais il est souvent moins utilisé au profit de modèles de données plus simples.

Source : - http://www-igm.univ-mlv.fr/~dr/XPOSE2010/Cassandra/modele.html

2.1.2 Les différentes clefs

- **Clef primaire** : Identifie de manière unique chaque enregistrement dans la table. Elle est formée de :
  - Clé de partition : Obligatoire.
  - Clés de clustering : Optionnelles.
- **Clef de partition** : Détermine sur quel nœud du cluster les données seront stockées. C'est la première composante de la clé primaire. Cassandra utilise un algorithme de hachage pour distribuer les partitions uniformément sur les nœuds. Tous les enregistrements ayant la même clé de partition seront stockés sur le même nœud (dans une partition).
- **Clef de clustering** : Organise les données au sein d'une partition. Fait partie de la clé primaire, mais intervient après la clé de partition. Les données sont triées dans l'ordre croissant (par défaut) ou décroissant au sein de chaque partition.
- **Clé secondaire** : Utilisée pour rechercher des données via une colonne qui n'est ni une clé de partition ni une clé de clustering. Cassandra génère un index secondaire pour accélérer les recherches sur cette colonne. Cependant, les performances peuvent être dégradées si l'index est utilisé pour des requêtes impliquant un balayage de nombreuses partitions. Une clé secondaire est définie en créant un **index** sur la colonne souhaitée.

Source: - https://www.baeldung.com/cassandra-keys

2.1.3 Architecture de Cassandra :

L'architecture de Cassandra est décentralisée et repose sur un modèle peer-to-peer, ce qui signifie qu'il n'y a pas de nœud maître ou de coordination centralisée. Tous les nœuds sont égaux et partagent le même rôle. Cela permet une grande scalabilité et une tolérance aux pannes.

- **Partitions et Réplication** : Cassandra répartit les données entre différents nœuds via un mécanisme de partitionnement basé sur un hash de la clé primaire. Chaque nœud du cluster stocke une portion des données, et des répliques de ces données peuvent être présentes sur plusieurs nœuds, selon la stratégie de réplication définie dans le Keyspace. Cela permet à Cassandra d'assurer une haute disponibilité, même en cas de panne d'un ou plusieurs nœuds.
- **Consistence et Quorum** : Cassandra suit un modèle de consistance configurable, permettant de choisir entre des garanties de consistance fortes ou une consistance plus faible en fonction des besoins. Cela se configure via les paramètres Read Consistency Level et Write Consistency Level. Par exemple, un niveau de consistance QUORUM signifie qu'une opération de lecture ou d'écriture devra être validée par la majorité des répliques d'une donnée avant de réussir.

Source: - https://www.geeksforgeeks.org/quorum-consistency-in-cassandra/

2.1.4 Requêtes et Modèle de Consistance :

Les requêtes dans Cassandra utilisent le Cassandra Query Language (CQL), qui ressemble à SQL mais avec des différences significatives adaptées aux particularités du modèle NoSQL.

- **Clé primaire et partitions** : Dans Cassandra, la clé primaire détermine comment les données sont partitionnées et distribuées à travers les nœuds du cluster comme expliqué plus haut. Il est essentiel de bien concevoir cette clé pour assurer des performances optimales.
- **Sélection et filtrage** : Cassandra fonctionne très bien pour les requêtes basées sur la clé primaire. Les requêtes qui filtrent sur d'autres colonnes nécessitent l'utilisation d'index secondaires ou d'une modélisation spécifique des données pour garantir de bonnes performances. Filtrer sur une colonne sans index lève l'erreur ALLOW FILTERING, ce qui signifie que la requête pourrait être très coûteuse en termes de performance.

2.1.5 Avantages et Inconvénients de Cassandra :

Avantages :

- **Haute scalabilité horizontale** :
  - Possibilité d'ajouter facilement des nœuds pour s'adapter à une augmentation soudaine de la demande
  - Architecture scalable de façon linéaire permettant de déployer des clusters "multi-node"
- **Résilience et tolérance aux pannes**
  - Réplication des données sur plusieurs nœuds pour garantir une haute disponibilité
  - Absence de point unique de défaillance
  - Capacité à continuer à fonctionner même en cas de panne d'un ou plusieurs nœuds
- **Flexibilité du modèle de données**
  - Prise en charge des données structurées, semi-structurées et non structurées
  - Possibilité d'ajouter de nouvelles colonnes sans affecter les données existantes
- **Performances élevées**
  - Impressionnante vitesse d'écriture de données
  - Capacité à traiter de vastes quantités de données dispersées entre de multiples serveurs

Inconvénients :

- L'un des principaux inconvénients de Cassandra réside dans la gestion des requêtes sur des colonnes non incluses dans la clé primaire, même lorsqu'un index est présent. Cela peut entraîner des problèmes de performances et nécessiter l'utilisation de la clause `ALLOW FILTERING`, qui est généralement déconseillée. Les index secondaires ne contiennent pas la clé de partition, ce qui oblige Cassandra à rechercher les données sur tous les nœuds du cluster. Cela peut être coûteux en termes de performances, surtout sur de grands clusters. La clause `ALLOW FILTERING` est nécessaire lorsque Cassandra ne peut pas garantir une exécution efficace de la requête. Cela se produit souvent pour des requêtes impliquant des comparaisons (comme $>$, $<$) ou plusieurs colonnes filtrées sans clé de partition précise.

Initialement, nous avons effectué les comparaisons pour les opérations SELECT, UPDATE et DELETE avec une condition sur `release_year > 2000` (toujours la même requête pour garantir la cohérence). Cependant, cette approche nécessitait l'utilisation de `ALLOW FILTERING`, ce qui empêchait de constater une réelle différence entre les cas avec ou sans index. Nous avons donc

modifié nos tests en utilisant `release_year = 2000`, ce qui a permis d'observer des variations plus significatives.

Sources : - https://www.lebigdata.fr/apache-cassandra-definition - https://datascientest.com/apache-cassandra - https://www.scnsoft.com/data/cassandra-performance

2.1.6 Conclusion :

Cassandra est une base de données extrêmement puissante pour les cas d'utilisation à grande échelle et hautement distribués, avec une grande tolérance aux pannes. Cependant, sa conception impose certaines contraintes sur la manière de structurer les données, et une bonne compréhension de son modèle de partitionnement est essentielle pour garantir de bonnes performances. Si l'application nécessite des requêtes complexes ou des jointures, il est déconseillé d'utiliser Cassandra, car il n'est pas conçu pour ce type de traitement sans outils supplémentaires.

2.2 Fonctionnement de SQLite

SQLite est une base de données relationnelle légère, autonome et sans serveur, idéale pour les applications nécessitant une gestion locale des données. Voici ses principales caractéristiques :

- **Base embarquée** : Contrairement à MySQL ou PostgreSQL, SQLite est intégré directement dans l'application sans serveur séparé. Les données sont stockées dans un fichier unique.
- **Structure relationnelle** : SQLite suit le modèle relationnel classique avec tables, colonnes et lignes, et prend en charge les requêtes SQL standards (SELECT, INSERT, UPDATE, DELETE).
- **Simplicité** : Pas de serveur à installer ni de configuration complexe, ce qui facilite son utilisation pour des prototypes, des applications mobiles ou locales.
- **Performance** : Bien que performant pour des données locales et de petite taille, SQLite n'est pas conçu pour des applications à grande échelle nécessitant scalabilité ou haute disponibilité.
- **Transactions ACID** : SQLite assure l'intégrité des données avec un modèle transactionnel garantissant l'atomicité et la cohérence, mais sa gestion des transactions simultanées est moins robuste que celle de systèmes plus avancés.

Avantages

- **Efficacité en mémoire** : SQLite nécessite peu de mémoire, ce qui la rend rapide et idéale pour des applications de toutes tailles.
- **Autonomie** : Il fonctionne sans serveur externe, ce qui simplifie son intégration et son utilisation.
- **Polyvalence** : SQLite supporte les commandes SQL standard et est compatible avec de nombreux formats de données, ce qui le rend populaire dans diverses applications comme Facebook ou WhatsApp.
- **Portabilité** : Les fichiers SQLite sont faciles à sauvegarder et transférer, sans dépendance à un serveur spécifique.

- **Fiabilité** : Moins sujet aux erreurs de mémoire ou limitations liées à la RAM, avec une faible consommation de ressources.
- **Libre de droits** : SQLite est en domaine public, sans licence, ce qui en fait une solution économique.

Limites

- **Absence de gestion multi-utilisateurs** : SQLite ne supporte pas plusieurs utilisateurs ou connexions simultanées, ce qui le rend limité pour les applications multi-clients.
- **Impact de la croissance des données** : La performance peut diminuer avec des volumes importants de données.
- **Limitation des requêtes client** : SQLite ne gère pas bien les requêtes client directes ou les connexions simultanées, ce qui peut causer des retards dans certaines applications.

Sources : - https://www.ionos.fr/digitalguide/sites-internet/developpement-web/sqlite/ - https://datascientest.com/sqlite-tout-savoir - https://www.tutlane.com/tutorial/sqlite/sqlite-acid-transactions - https://blog.stephane-robert.info/docs/services/bdd/relationnelles/sqlite/

2.3 Installer les outils

[1]:
```
!pip install plotly matplotlib pandas numpy cassandra_driver kagglehub tabulate
```

```
Defaulting to user installation because normal site-packages is not writeable
Requirement already satisfied: plotly in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (5.24.1)
Requirement already satisfied: matplotlib in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (3.9.2)
Requirement already satisfied: pandas in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (2.2.3)
Requirement already satisfied: numpy in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (1.26.4)
Requirement already satisfied: cassandra_driver in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (3.29.2)
Requirement already satisfied: kagglehub in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (0.3.5)
Requirement already satisfied: tabulate in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (0.9.0)
Requirement already satisfied: tenacity>=6.2.0 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from plotly)
(9.0.0)
Requirement already satisfied: packaging in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from plotly)
(24.2)
Requirement already satisfied: contourpy>=1.0.1 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(1.3.0)
```

```
Requirement already satisfied: cycler>=0.10 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(4.55.0)
Requirement already satisfied: kiwisolver>=1.3.1 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(1.4.7)
Requirement already satisfied: pillow>=8 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(11.0.0)
Requirement already satisfied: pyparsing>=2.3.1 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(3.2.0)
Requirement already satisfied: python-dateutil>=2.7 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(2.9.0.post0)
Requirement already satisfied: importlib-resources>=3.2.0 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from matplotlib)
(6.4.5)
Requirement already satisfied: pytz>=2020.1 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from pandas)
(2024.2)
Requirement already satisfied: tzdata>=2022.7 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from pandas)
(2024.2)
Requirement already satisfied: geomet<0.3,>=0.1 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from
cassandra_driver) (0.2.1.post1)
Requirement already satisfied: requests in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from kagglehub)
(2.32.3)
Requirement already satisfied: tqdm in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from kagglehub)
(4.67.1)
Requirement already satisfied: click in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from
geomet<0.3,>=0.1->cassandra_driver) (8.1.7)
Requirement already satisfied: six in /Library/Developer/CommandLineTools/Librar
y/Frameworks/Python3.framework/Versions/3.9/lib/python3.9/site-packages (from
geomet<0.3,>=0.1->cassandra_driver) (1.15.0)
Requirement already satisfied: zipp>=3.1.0 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from importlib-
resources>=3.2.0->matplotlib) (3.21.0)
Requirement already satisfied: charset-normalizer<4,>=2 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from
requests->kagglehub) (3.4.0)
```

```
Requirement already satisfied: idna<4,>=2.5 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from
requests->kagglehub) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from
requests->kagglehub) (2.2.3)
Requirement already satisfied: certifi>=2017.4.17 in
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages (from
requests->kagglehub) (2024.8.30)
```

[2]:
```
# importer toutes les librairies nécessaires
from cassandra.cluster import Cluster

import kagglehub

import matplotlib.pyplot as plt

import numpy as np

import os

import pandas as pd

import random

import sqlite3

from tabulate import tabulate
import time
import tracemalloc
```

```
/Users/zoemarquis/Library/Python/3.9/lib/python/site-
packages/urllib3/__init__.py:35: NotOpenSSLWarning: urllib3 v2 only supports
OpenSSL 1.1.1+, currently the 'ssl' module is compiled with 'LibreSSL 2.8.3'.
See: https://github.com/urllib3/urllib3/issues/3020
  warnings.warn(
/Users/zoemarquis/Library/Python/3.9/lib/python/site-packages/tqdm/auto.py:21:
TqdmWarning: IProgress not found. Please update jupyter and ipywidgets. See
https://ipywidgets.readthedocs.io/en/stable/user_install.html
  from .autonotebook import tqdm as notebook_tqdm
```

2.4 Importation des données

[3]:
```
path = kagglehub.dataset_download("shivamb/netflix-shows")
print("Chemin vers le fichier du dataset : ", path)
```

```
Chemin vers le fichier du dataset :
/Users/zoemarquis/.cache/kagglehub/datasets/shivamb/netflix-shows/versions/5
```

[4]:
```
files = os.listdir(path)
print("Nom du fichier : ", files)
```

```
Nom du fichier :  ['netflix_titles.csv']
```

[5]:
```
filename = f"{path}/{files[0]}"
df_initial = pd.read_csv(filename)
```

[6]:
```
print(tabulate(df_initial.head(10), headers='keys', tablefmt='psql'))
```

```
+----+-----------+---------+-----------------------------------+-----------------
-------------+-------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
+-------------------------------------------------------------------------+-------
-------------+----------------+----------+------------+-----------------------
-------------------------------------+---------------------------------------
-------------------------------------------------------------------------------
----------------------------------+
|    | show_id   | type    | title                             | director
| cast
| country                                                                    |
date_added         |   release_year | rating   | duration   | listed_in
| description
|
|----+-----------+---------+-----------------------------------+-----------------
-------------+-------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
+-------------------------------------------------------------------------+-------
-------------+----------------+----------+------------+-----------------------
-------------------------------------+---------------------------------------
-------------------------------------------------------------------------------
----------------------------------|
|  0 | s1        | Movie   | Dick Johnson Is Dead              | Kirsten Johnson
| nan
| United States                                                              |
September 25, 2021 |           2020 | PG-13    | 90 min     | Documentaries
| As her father nears the end of his life, filmmaker Kirsten Johnson stages his
death in inventive and comical ways to help them both face the inevitable.  |
|  1 | s2        | TV Show | Blood & Water                     | nan
| Ama Qamata, Khosi Ngema, Gail Mabalane, Thabang Molaba, Dillon Windvogel,
Natasha Thahane, Arno Greeff, Xolile Tshabalala, Getmore Sithole, Cindy
Mahlangu, Ryle De Morny, Greteli Fincham, Sello Maake Ka-Ncube, Odwa Gwanya,
Mekaila Mathys, Sandi Schultz, Duane Williams, Shamilla Miller, Patrick Mofokeng
| South Africa                                                               |
```

September 24, 2021 | 2021 | TV-MA | 2 Seasons | International TV Shows, TV Dramas, TV Mysteries | After crossing paths at a party, a Cape Town teen sets out to prove whether a private-school swimming star is her sister who was abducted at birth. |
| 2 | s3 | TV Show | Ganglands | Julien Leclercq
| Sami Bouajila, Tracy Gotoas, Samuel Jouy, Nabiha Akkari, Sofia Lesaffre, Salim Kechiouche, Noureddine Farihi, Geert Van Rampelberg, Bakary Diombera
| nan |
September 24, 2021 | 2021 | TV-MA | 1 Season | Crime TV Shows, International TV Shows, TV Action & Adventure | To protect his family from a powerful drug lord, skilled thief Mehdi and his expert team of robbers are pulled into a violent and deadly turf war. |
| 3 | s4 | TV Show | Jailbirds New Orleans | nan
| nan
| nan |
September 24, 2021 | 2021 | TV-MA | 1 Season | Docuseries, Reality TV | Feuds, flirtations and toilet talk go down among the incarcerated women at the Orleans Justice Center in New Orleans on this gritty reality series. |
| 4 | s5 | TV Show | Kota Factory | nan
| Mayur More, Jitendra Kumar, Ranjan Raj, Alam Khan, Ahsaas Channa, Revathi Pillai, Urvi Singh, Arun Kumar
| India |
September 24, 2021 | 2021 | TV-MA | 2 Seasons | International TV Shows, Romantic TV Shows, TV Comedies | In a city of coaching centers known to train India's finest collegiate minds, an earnest but unexceptional student and his friends navigate campus life. |
| 5 | s6 | TV Show | Midnight Mass | Mike Flanagan
| Kate Siegel, Zach Gilford, Hamish Linklater, Henry Thomas, Kristin Lehman, Samantha Sloyan, Igby Rigney, Rahul Kohli, Annarah Cymone, Annabeth Gish, Alex Essoe, Rahul Abburi, Matt Biedel, Michael Trucco, Crystal Balint, Louis Oliver
| nan |
September 24, 2021 | 2021 | TV-MA | 1 Season | TV Dramas, TV Horror, TV Mysteries | The arrival of a charismatic young priest brings glorious miracles, ominous mysteries and renewed religious fervor to a dying town desperate to believe. |
| 6 | s7 | Movie | My Little Pony: A New Generation | Robert Cullen, José Luis Ucha | Vanessa Hudgens, Kimiko Glenn, James Marsden, Sofia Carson, Liza Koshy, Ken Jeong, Elizabeth Perkins, Jane Krakowski, Michael McKean, Phil LaMarr
| nan |
September 24, 2021 | 2021 | PG | 91 min | Children & Family Movies | Equestria's divided. But a bright-eyed hero believes Earth Ponies, Pegasi and Unicorns should be pals - and, hoof to heart, she's determined to prove it. |
| 7 | s8 | Movie | Sankofa | Haile Gerima
| Kofi Ghanaba, Oyafunmike Ogunlano, Alexandra Duah, Nick Medley, Mutabaruka, Afemo Omilami, Reggie Carter, Mzuri

```
| United States, Ghana, Burkina Faso, United Kingdom, Germany, Ethiopia |
September 24, 2021 |          1993 | TV-MA    | 125 min    | Dramas,
Independent Movies, International Movies              | On a photo shoot in
Ghana, an American model slips back in time, becomes enslaved on a plantation
and bears witness to the agony of her ancestral past.   |
|  8 | s9        | TV Show | The Great British Baking Show    | Andy Devonshire
| Mel Giedroyc, Sue Perkins, Mary Berry, Paul Hollywood
| United Kingdom                                                          |
September 24, 2021 |          2021 | TV-14    | 9 Seasons  | British TV Shows,
Reality TV                                    | A talented batch of amateur bakers
face off in a 10-week competition, whipping up their best dishes in the hopes of
being named the U.K.'s best.          |
|  9 | s10       | Movie   | The Starling                     | Theodore Melfi
| Melissa McCarthy, Chris O'Dowd, Kevin Kline, Timothy Olyphant, Daveed Diggs,
Skyler Gisondo, Laura Harrier, Rosalind Chao, Kimberly Quinn, Loretta Devine,
Ravi Kapoor
| United States                                                           |
September 24, 2021 |          2021 | PG-13    | 104 min    | Comedies, Dramas
| A woman adjusting to life after a loss contends with a feisty bird that's
taken over her garden - and a husband who's struggling to find a way forward.
|
+----+----------+---------+---------------------------------+----------------
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-------------------------------------------------------------------------
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+-------------------------------------------------------------------------+-------
------------+----------------+----------+------------+-----------------------
-------------------------------------+-----------------------------------------
-------------------------------------------------------------------------
----------------------------------+
```

[7]:
```
# afficher le nombre de lignes dans le dataset
print(f"Nombre de lignes : {len(df_initial)}")
```

```
Nombre de lignes : 8807
```

[8]:
```
# types des colonnes
print(df_initial.dtypes)
```

```
show_id         object
type            object
title           object
director        object
cast            object
country         object
date_added      object
release_year     int64
rating          object
```

```
duration        object
listed_in       object
description     object
dtype: object
```

[9]:
```
# Convertir la colonne show_id en int en enlevant le préfixe 's'
# (plus simple pour gérer exactement le meme type de données en Cassandra et␣
 ↪SQLite)
df_initial['show_id'] = df_initial['show_id'].str.replace('s', '').astype(int).
 ↪astype(int)

df_initial['show_id'] = df_initial['show_id'].astype(int)
df_initial['release_year'] = df_initial['release_year'].astype(int)

df_initial['type'] = df_initial['title'].astype(str)
df_initial['title'] = df_initial['title'].astype(str)
df_initial['director'] = df_initial['director'].astype(str)
df_initial['cast'] = df_initial['cast'].astype(str)
df_initial['country'] = df_initial['country'].astype(str)
df_initial['date_added'] = df_initial['date_added'].astype(str)
df_initial['rating'] = df_initial['rating'].astype(str)
df_initial['duration'] = df_initial['duration'].astype(str)
df_initial['listed_in'] = df_initial['listed_in'].astype(str)
df_initial['description'] = df_initial['description'].astype(str)
```

[10]:
```
# types des colonnes
print(df_initial.dtypes)
```

```
show_id          int64
type            object
title           object
director        object
cast            object
country         object
date_added      object
release_year     int64
rating          object
duration        object
listed_in       object
description     object
dtype: object
```

2.5 CRUD : Create, Read, Update, Delete

- Create (*Insert*) : Insérer des données dans la base de données.
- Read (*Select*) : Récupérer des données.
- Update (*Update*) : Modifier des données existantes.
- Delete (*Delete*) : Effacer des données.

[11]:
```
schema = """
CREATE TABLE IF NOT EXISTS shows (
    show_id INT PRIMARY KEY,
    title TEXT,
    type TEXT,
    director TEXT,
    cast TEXT,
    country TEXT,
    date_added TEXT,
    release_year INT,
    rating TEXT,
    duration TEXT,
    listed_in TEXT,
    description TEXT
);
"""
```

[12]:
```
# création d'une donnée de test : une ligne pour le film Zoé & Charlotte
data_zoe_charlotte = {
    'show_id': [0],
    'title': ['Zoé & Charlotte'],
    'type': ['Movie'],
    'director': ['Christopher Nolan'],
    'cast': ['Leonardo DiCaprio, Joseph Gordon-Levitt'],
    'country': ['USA'],
    'date_added': ['2021-01-01'],
    'release_year': [2000],
    'rating': ['PG-13'],
    'duration': ['148 min'],
    'listed_in': ['Action, Sci-Fi'],
    'description': ['A thief who steals corporate secrets through the use of␣
 ↪dream-sharing technology is given the inverse task of planting an idea into␣
 ↪the mind of a CEO.']
}
df_zoe_charlotte = pd.DataFrame(data_zoe_charlotte)
```

2.5.1 SQLite

[13]:
```
# Créer une base de données SQLite en mémoire
conn = sqlite3.connect(':memory:')
cursor = conn.cursor()

def drop_table_sqlite():
    cursor.execute("DROP TABLE IF EXISTS shows;")
    conn.commit()

def create_table_sqlite():
```

```
    cursor.execute(schema)
    conn.commit()

drop_table_sqlite()
create_table_sqlite()
```

[14]:
```
# SQLite : fonctions pour insérer, lire, mettre à jour et supprimer des données␣
 ↪à utiliser pour le benchmark
# on récupère le temps, la mémoire courante et la mémoire maximale utilisée␣
 ↪pour chaque opération

# --- CREATE ---
def sqlite_insert(df):
    drop_table_sqlite()
    create_table_sqlite()
    columns = ', '.join(df.columns)
    placeholders = ', '.join(['?'] * len(df.columns))
    insert_query = f"INSERT INTO shows ({columns}) VALUES ({placeholders})"

    tracemalloc.start()
    start_time = time.time()
    for _, row in df.iterrows():
      cursor.execute(insert_query, tuple(row))
    conn.commit()

    create_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Create Time: {create_time_sqlite:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return create_time_sqlite, current, peak

# --- READ ---
def sqlite_read(df):
    sqlite_insert(df)

    tracemalloc.start()
    start_time = time.time()
    cursor.execute("SELECT * FROM shows WHERE release_year = 2000")
    result = cursor.fetchall()
    read_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
```

```
    print(f"Read Time: {read_time_sqlite:.6f} seconds")
    print(f"Queried {len(result)} records")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return read_time_sqlite, current, peak

# --- UPDATE ---
def sqlite_update(df):
    sqlite_insert(df)

    tracemalloc.start()
    start_time = time.time()
    cursor.execute("UPDATE shows SET rating='PG' WHERE release_year = 2000")
    conn.commit()
    update_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()

    print(f"Update Time: {update_time_sqlite:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return update_time_sqlite, current, peak

# --- DELETE ---
def sqlite_delete(df):
    sqlite_insert(df)

    tracemalloc.start()
    start_time = time.time()
    cursor.execute("DELETE FROM shows WHERE release_year = 2000")
    conn.commit()
    delete_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Delete Time: {delete_time_sqlite:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return delete_time_sqlite, current, peak
```

[15]:
```
# Fonction pour effectuer une opération plusieurs fois et calculer la moyenne␣
 ↪et l'écart-type
def benchmark_operation(func, *args):
    times = []
    current_memory = []
    peak_memory = []
    for _ in range(5):  # Effectuer 5 itérations
```

```
        temps, current, peak = func(*args)  # Exécuter la fonction avec les␣
 ↪arguments
        times.append(temps)
        current_memory.append(current)
        peak_memory.append(peak)

    # Calculer la moyenne et l'écart-type
    mean_time = np.mean(times)
    std_time = np.std(times)
    mean_current_memory = np.mean(current_memory)
    std_current_memory = np.std(current_memory)
    mean_peak_memory = np.mean(peak_memory)
    std_peak_memory = np.std(peak_memory)
    return mean_time, std_time, mean_current_memory, std_current_memory,␣
 ↪mean_peak_memory, std_peak_memory

# --- CREATE ---
create_sqlite_simple_mean_time, create_sqlite_simple_std_time, \
    create_sqlite_simple_mean_current_memory,␣
 ↪create_sqlite_simple_std_current_memory, \
        create_sqlite_simple_mean_peak_memory,␣
 ↪create_sqlite_simple_std_peak_memory = benchmark_operation(sqlite_insert,␣
 ↪df_zoe_charlotte)

# --- READ ---
read_sqlite_simple_mean_time, read_sqlite_simple_std_time, \
    read_sqlite_simple_mean_current_memory,␣
 ↪read_sqlite_simple_std_current_memory, \
        read_sqlite_simple_mean_peak_memory, read_sqlite_simple_std_peak_memory␣
 ↪= benchmark_operation(sqlite_read, df_zoe_charlotte)

# --- UPDATE ---
update_sqlite_simple_mean_time, update_sqlite_simple_std_time, \
    update_sqlite_simple_mean_current_memory,␣
 ↪update_sqlite_simple_std_current_memory, \
        update_sqlite_simple_mean_peak_memory,␣
 ↪update_sqlite_simple_std_peak_memory = benchmark_operation(sqlite_update,␣
 ↪df_zoe_charlotte)

# --- DELETE ---
delete_sqlite_simple_mean_time, delete_sqlite_simple_std_time, \
    delete_sqlite_simple_mean_current_memory,␣
 ↪delete_sqlite_simple_std_current_memory, \
        delete_sqlite_simple_mean_peak_memory,␣
 ↪delete_sqlite_simple_std_peak_memory = benchmark_operation(sqlite_delete,␣
 ↪df_zoe_charlotte)
```

```
Create Time: 0.000498 seconds
Current memory usage is 0.002162933349609375Mo; Peak was 0.003635406494140625Mo
Create Time: 0.000463 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Create Time: 0.000135 seconds
Current memory usage is 0.00130844116210937 5Mo; Peak was 0.003093719482421875Mo
Create Time: 0.000107 seconds
Current memory usage is 0.00130844116210937 5Mo; Peak was 0.003093719482421875Mo
Create Time: 0.000101 seconds
Current memory usage is 0.00130844116210937 5Mo; Peak was 0.003093719482421875Mo
Create Time: 0.000106 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Read Time: 0.000024 seconds
Queried 1 records
Current memory usage is 0.0023555755615234375Mo; Peak was
0.0024013519287109375Mo
Create Time: 0.000099 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Read Time: 0.000016 seconds
Queried 1 records
Current memory usage is 0.0014476776123046875Mo; Peak was
0.0014934539794921875Mo
Create Time: 0.000095 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Read Time: 0.000014 seconds
Queried 1 records
Current memory usage is 0.0014476776123046875Mo; Peak was
0.0014934539794921875Mo
Create Time: 0.000094 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Read Time: 0.000014 seconds
Queried 1 records
Current memory usage is 0.0014476776123046875Mo; Peak was
0.0014934539794921875Mo
Create Time: 0.000094 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Read Time: 0.000013 seconds
Queried 1 records
Current memory usage is 0.0014476776123046875Mo; Peak was
0.0014934539794921875Mo
Create Time: 0.000097 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Update Time: 0.000009 seconds
Current memory usage is 0.0002365112304687 5Mo; Peak was 0.00031280517578125Mo
Create Time: 0.000095 seconds
Current memory usage is 0.00128552978515625Mo; Peak was 0.003093719482421875Mo
Update Time: 0.000007 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
```

```
Create Time: 0.000092 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Update Time: 0.000006 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
Create Time: 0.000090 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Update Time: 0.000008 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
Create Time: 0.000091 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Update Time: 0.000006 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
Create Time: 0.000234 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Delete Time: 0.000010 seconds
Current memory usage is 0.000457763671875Mo; Peak was 0.0005340576171875Mo
Create Time: 0.000100 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Delete Time: 0.000007 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
Create Time: 0.000094 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Delete Time: 0.000006 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
Create Time: 0.000092 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Delete Time: 0.000006 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
Create Time: 0.000106 seconds
Current memory usage is 0.00128555297851562 5Mo; Peak was 0.00309371948242187 5Mo
Delete Time: 0.000011 seconds
Current memory usage is 0.0Mo; Peak was 7.62939453125e-05Mo
```

Test de l'insertion avec une ligne de DataFrame Nous avons d'abord testé l'insertion d'une seule ligne de données extraite d'un DataFrame dans notre base de données.

Cette étape permet de vérifier que l'insertion fonctionne correctement sur un cas simple, avant de passer à l'insertion de l'ensemble du DataFrame.

À ce stade, l'insertion a été réalisée avec succès sur une ligne de données, ce qui nous permet d'assurer que la logique de base est correcte.

Nous allons maintenant procéder à l'insertion du DataFrame complet pour tester la gestion de plusieurs lignes et évaluer les performances d'insertion à plus grande échelle.

[16]:
```
# --- CREATE ---
create_sqlite_initial_mean_time, create_sqlite_initial_std_time, \
    create_sqlite_initial_mean_current_memory,␣
 ↪create_sqlite_initial_std_current_memory,\
```

```
    create_sqlite_initial_mean_peak_memory,␣
 ↪create_sqlite_initial_std_peak_memory  = benchmark_operation(sqlite_insert,␣
 ↪df_initial)

# --- READ ---
read_sqlite_initial_mean_time, read_sqlite_initial_std_time, \
    read_sqlite_initial_mean_current_memory,␣
 ↪read_sqlite_initial_std_current_memory,\
    read_sqlite_initial_mean_peak_memory, read_sqlite_initial_std_peak_memory =␣
 ↪benchmark_operation(sqlite_read, df_initial)

# --- UPDATE ---
update_sqlite_initial_mean_time, update_sqlite_initial_std_time, \
    update_sqlite_initial_mean_current_memory,␣
 ↪update_sqlite_initial_std_current_memory,\
    update_sqlite_initial_mean_peak_memory,␣
 ↪update_sqlite_initial_std_peak_memory = benchmark_operation(sqlite_update,␣
 ↪df_initial)

# --- DELETE ---
delete_sqlite_initial_mean_time, delete_sqlite_initial_std_time, \
    delete_sqlite_initial_mean_current_memory,␣
 ↪delete_sqlite_initial_std_current_memory,\
    delete_sqlite_initial_mean_peak_memory,␣
 ↪delete_sqlite_initial_std_peak_memory = benchmark_operation(sqlite_delete,␣
 ↪df_initial)
```

```
Create Time: 0.429758 seconds
Current memory usage is 1.6778736114501953Mo; Peak was 1.6804027557373047Mo
Create Time: 0.370335 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Create Time: 0.351580 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Create Time: 0.350778 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Create Time: 0.355296 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Create Time: 0.357078 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Read Time: 0.000649 seconds
Queried 37 records
Current memory usage is 0.04055595397949219Mo; Peak was 0.04055595397949219Mo
Create Time: 0.354897 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Read Time: 0.000742 seconds
Queried 37 records
Current memory usage is 0.03601646423339844Mo; Peak was 0.03601646423339844Mo
```

```
Create Time: 0.355182 seconds
Current memory usage is 1.2717657089233398Mo; Peak was 1.4052963256835938Mo
Read Time: 0.000678 seconds
Queried 37 records
Current memory usage is 0.03601646423339844Mo; Peak was 0.03601646423339844Mo
Create Time: 0.353552 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Read Time: 0.000702 seconds
Queried 37 records
Current memory usage is 0.03601646423339844Mo; Peak was 0.03601646423339844Mo
Create Time: 0.364964 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Read Time: 0.000720 seconds
Queried 37 records
Current memory usage is 0.03601646423339844Mo; Peak was 0.03601646423339844Mo
Create Time: 0.357937 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Update Time: 0.000496 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.352563 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Update Time: 0.000517 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.351067 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Update Time: 0.000623 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.362179 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Update Time: 0.000508 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.355694 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Update Time: 0.000801 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.364194 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Delete Time: 0.000646 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.355080 seconds
Current memory usage is 1.2714948654174805Mo; Peak was 1.4052963256835938Mo
Delete Time: 0.000655 seconds
```

```
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.356947 seconds
Current memory usage is 1.2714414596557617Mo; Peak was 1.405242919921875Mo
Delete Time: 0.000728 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.353286 seconds
Current memory usage is 1.2714414596557617Mo; Peak was 1.405242919921875Mo
Delete Time: 0.000645 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 0.359351 seconds
Current memory usage is 1.2739591598510742Mo; Peak was 1.405242919921875Mo
Delete Time: 0.000764 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
```

2.5.2 Cassandra

[17]:
```
# vérifier l'état actuel du noeud Cassandra
!nodetool status
```

```
Datacenter: datacenter1
=======================
Status=Up/Down
|/ State=Normal/Leaving/Joining/Moving
--  Address    Load       Tokens  Owns (effective)  Host ID
Rack
UN  127.0.0.1  2,13 MiB  16      100,0%
11c2e131-3642-40ab-a44b-5d5e95f42edb  rack1
```

[18]:
```
# Connexion à Cassandra
cluster = Cluster(['127.0.0.1'])
session = cluster.connect()


def drop_table_cassandra():
    session.execute("""
        DROP TABLE IF EXISTS netflix.shows;
        """)
    session.execute("""
        DROP KEYSPACE IF EXISTS netflix;
        """)

def create_table_cassandra(replication_factor):
    session.execute(f"""
```

```
        CREATE KEYSPACE netflix
        WITH REPLICATION = {{
            'class': 'SimpleStrategy',
            'replication_factor': {replication_factor}
        }};
        """)
    session.set_keyspace('netflix')
    session.execute(schema)
    print(f"replication factor = {replication_factor}")


drop_table_cassandra()
create_table_cassandra(1)
```

```
replication factor = 1
```

Test sans index Pour l'instant, nous effectuons les tests sans index. Cette approche nous permettra d'évaluer les performances de base. Nous ajouterons ensuite des index pour comparer les résultats et analyser l'impact sur les performances des requêtes.

[19]:
```
# Cassandra : fonctions pour insérer, lire, mettre à jour et supprimer des␣
 ↪données à utiliser pour le benchmark
# on récupère le temps, la mémoire courante et la mémoire maximale utilisée␣
 ↪pour chaque opération

# nb_repl : pour la suite, on va tester avec 1, 2 et 5 replica

# Attention ici aux commentaires : on a besoin d'utiliser allow filtering, et␣
 ↪de faire un select avant de faire un update ou un delete :
# on explique pourquoi plus loin

# --- CREATE ---
def cassandra_insert(*args):
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques

    drop_table_cassandra()
    create_table_cassandra(nb_repl)

    insert_query = session.prepare("INSERT INTO shows (show_id, title,␣
 ↪director, cast, country, date_added, release_year, rating, duration,␣
 ↪listed_in, description) VALUES (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)")

    tracemalloc.start()
    start_time = time.time()
    for _, row in df.iterrows():
```

```
        session.execute(insert_query, (row['show_id'], row['title'],␣
 ↪row['director'], row['cast'], row['country'], row['date_added'],␣
 ↪row['release_year'], row['rating'], row['duration'], row['listed_in'],␣
 ↪row['description']))
    create_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()

    print(f"Create Time: {create_time:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")

    return create_time, current, peak

# --- READ ---
def cassandra_read(*args):
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques

    cassandra_insert(df, nb_repl)

    tracemalloc.start()
    start_time = time.time()
    # On utilise ici ALLOW FILTERING car release_year ne fait pas partie de la␣
 ↪clef primaire et n'est pas indexé
    result = session.execute("SELECT * FROM shows WHERE release_year = 2000␣
 ↪ALLOW FILTERING")
    read_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Read Time: {read_time:.6f} seconds")
    num_records = sum(1 for _ in result)
    print(f"Queried {num_records} records")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return read_time, current, peak

# --- UPDATE ---
def cassandra_update(*args):
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques

    cassandra_insert(df, nb_repl)

    tracemalloc.start()
```

```
    # On doit faire select et update car realease_year ne fait pas partie de la␣
 ↪clef primaire
    start_time = time.time()

    select_query = "SELECT show_id FROM shows WHERE release_year = 2000 ALLOW␣
 ↪FILTERING;"
    result = session.execute(select_query)
    show_ids_to_update = [row.show_id for row in result]

    for show_id in show_ids_to_update:
        update_query = f"UPDATE shows SET rating = 'PG' WHERE show_id =␣
 ↪{show_id};"
        session.execute(update_query)

    update_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Update Time: {update_time:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return update_time, current, peak

# --- DELETE ---
def cassandra_delete(*args):
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques

    cassandra_insert(df, nb_repl)

    # Comme pour update
    tracemalloc.start()
    start_time = time.time()

    select_query = "SELECT show_id FROM shows WHERE release_year = 2000 ALLOW␣
 ↪FILTERING;"
    result = session.execute(select_query)
    show_ids_to_delete = [row.show_id for row in result]

    for show_id in show_ids_to_delete:
        delete_query = f"DELETE FROM shows WHERE show_id = {show_id};"
        session.execute(delete_query)

    delete_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
```

```
    tracemalloc.stop()
    print(f"Delete Time: {delete_time:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return delete_time, current, peak
```

[20]:
```
# --- CREATE ---
create_cassandra_simple_mean_time, create_cassandra_simple_std_time, \
    create_cassandra_simple_mean_current_memory,␣
 ↪create_cassandra_simple_std_current_memory, \
        create_cassandra_simple_mean_peak_memory,␣
 ↪create_cassandra_simple_std_peak_memory  =␣
 ↪benchmark_operation(cassandra_insert, df_zoe_charlotte, 1)

# --- READ ---
read_cassandra_simple_mean_time, read_cassandra_simple_std_time, \
    read_cassandra_simple_mean_current_memory,␣
 ↪read_cassandra_simple_std_current_memory, \
        read_cassandra_simple_mean_peak_memory,␣
 ↪read_cassandra_simple_std_peak_memory  = benchmark_operation(cassandra_read,␣
 ↪df_zoe_charlotte, 1)

# --- UPDATE ---
update_cassandra_simple_mean_time, update_cassandra_simple_std_time, \
    update_cassandra_simple_mean_current_memory,␣
 ↪update_cassandra_simple_std_current_memory, \
        update_cassandra_simple_mean_peak_memory,␣
 ↪update_cassandra_simple_std_peak_memory  =␣
 ↪benchmark_operation(cassandra_update, df_zoe_charlotte, 1)

# --- DELETE ---
delete_cassandra_simple_mean_time, delete_cassandra_simple_std_time,  \
    delete_cassandra_simple_mean_current_memory,␣
 ↪delete_cassandra_simple_std_current_memory,  \
        delete_cassandra_simple_mean_peak_memory,␣
 ↪delete_cassandra_simple_std_peak_memory  =␣
 ↪benchmark_operation(cassandra_delete, df_zoe_charlotte, 1)
```

```
replication factor = 1
Create Time: 0.001940 seconds
Current memory usage is 0.017141342163085938Mo; Peak was 0.021819114685058594Mo
replication factor = 1
Create Time: 0.002795 seconds
Current memory usage is 0.0066680908203125Mo; Peak was 0.011345863342285156Mo
replication factor = 1
Create Time: 0.002871 seconds
Current memory usage is 0.006988525390625Mo; Peak was 0.011666297912597656Mo
replication factor = 1
```

```
Create Time: 0.002644 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
replication factor = 1
Create Time: 0.002840 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
replication factor = 1
Create Time: 0.002593 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Read Time: 0.002979 seconds
Queried 1 records
Current memory usage is 0.012293815612792969Mo; Peak was 0.04300212860107422Mo
replication factor = 1
Create Time: 0.002093 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Read Time: 0.002039 seconds
Queried 1 records
Current memory usage is 0.010393142700195312Mo; Peak was 0.04158973693847656Mo
replication factor = 1
Create Time: 0.002393 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Read Time: 0.002307 seconds
Queried 1 records
Current memory usage is 0.011064529418945312Mo; Peak was 0.04177284240722656Mo
replication factor = 1
Create Time: 0.002291 seconds
Current memory usage is 0.006649017333984375Mo; Peak was 0.011300086975097656Mo
Read Time: 0.002436 seconds
Queried 1 records
Current memory usage is 0.011663436889648438Mo; Peak was 0.04179954528808594Mo
replication factor = 1
Create Time: 0.002686 seconds
Current memory usage is 0.0068817138671875Mo; Peak was 0.011559486389160156Mo
Read Time: 0.001966 seconds
Queried 1 records
Current memory usage is 0.010393142700195312Mo; Peak was 0.04158973693847656Mo
replication factor = 1
Create Time: 0.002082 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Update Time: 0.002011 seconds
Current memory usage is 0.0124053955078125Mo; Peak was 0.01834392547607422Mo
replication factor = 1
Create Time: 0.002270 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Update Time: 0.003024 seconds
Current memory usage is 0.0107421875Mo; Peak was 0.01757335662841797Mo
replication factor = 1
Create Time: 0.002411 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
```

```
Update Time: 0.003033 seconds
Current memory usage is 0.01007080078125Mo; Peak was 0.01739025115966797Mo
replication factor = 1
Create Time: 0.001800 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Update Time: 0.002197 seconds
Current memory usage is 0.0200653076171875Mo; Peak was 0.023987770080566406Mo
replication factor = 1
Create Time: 0.002363 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Update Time: 0.002639 seconds
Current memory usage is 0.0107421875Mo; Peak was 0.01757335662841797Mo
replication factor = 1
Create Time: 0.002311 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Delete Time: 0.002938 seconds
Current memory usage is 0.010090827941894531Mo; Peak was 0.01739025115966797Mo
replication factor = 1
Create Time: 0.002165 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Delete Time: 0.002897 seconds
Current memory usage is 0.012171745300292969Mo; Peak was 0.01852703094482422Mo
replication factor = 1
Create Time: 0.002239 seconds
Current memory usage is 0.006622314453125Mo; Peak was 0.011300086975097656Mo
Delete Time: 0.002855 seconds
Current memory usage is 0.010729789733886719Mo; Peak was 0.01757335662841797Mo
replication factor = 1
Create Time: 0.002323 seconds
Current memory usage is 0.006649017333984375Mo; Peak was 0.011300086975097656Mo
Delete Time: 0.002937 seconds
Current memory usage is 0.010111808776855469Mo; Peak was 0.017416954040527344Mo
replication factor = 1
Create Time: 0.002641 seconds
Current memory usage is 0.006649017333984375Mo; Peak was 0.011300086975097656Mo
Delete Time: 0.002610 seconds
Current memory usage is 0.012225151062011719Mo; Peak was 0.018088340759277344Mo
```

[21]:
```
# --- CREATE ---
create_cassandra_initial_mean_time, create_cassandra_initial_std_time, \
    create_cassandra_initial_mean_current_memory,␣
 ↪create_cassandra_initial_std_current_memory, \
       create_cassandra_initial_mean_peak_memory,␣
 ↪create_cassandra_initial_std_peak_memory =␣
 ↪benchmark_operation(cassandra_insert, df_initial, 1)

# --- READ ---
```

```
read_cassandra_initial_mean_time, read_cassandra_initial_std_time, \
    read_cassandra_initial_mean_current_memory,␣
 ↪read_cassandra_initial_std_current_memory, \
        read_cassandra_initial_mean_peak_memory,␣
 ↪read_cassandra_initial_std_peak_memory = benchmark_operation(cassandra_read,␣
 ↪df_initial, 1)

# --- UPDATE ---
update_cassandra_initial_mean_time, update_cassandra_initial_std_time, \
    update_cassandra_initial_mean_current_memory,␣
 ↪update_cassandra_initial_std_current_memory, \
        update_cassandra_initial_mean_peak_memory,␣
 ↪update_cassandra_initial_std_peak_memory =␣
 ↪benchmark_operation(cassandra_update, df_initial, 1)

# --- DELETE ---
delete_cassandra_initial_mean_time, delete_cassandra_initial_std_time, \
    delete_cassandra_initial_mean_current_memory,␣
 ↪delete_cassandra_initial_std_current_memory, \
        delete_cassandra_initial_mean_peak_memory,␣
 ↪delete_cassandra_initial_std_peak_memory =␣
 ↪benchmark_operation(cassandra_delete, df_initial, 1)
```

```
replication factor = 1
Create Time: 4.057866 seconds
Current memory usage is 1.6043586730957031Mo; Peak was 1.6512699127197266Mo
replication factor = 1
Create Time: 4.130202 seconds
Current memory usage is 1.5310869216918945Mo; Peak was 1.6230592727661133Mo
replication factor = 1
Create Time: 4.102226 seconds
Current memory usage is 1.495941162109375Mo; Peak was 1.6345911026000977Mo
replication factor = 1
Create Time: 4.079000 seconds
Current memory usage is 1.599349021911621Mo; Peak was 1.6219959259033203Mo
replication factor = 1
Create Time: 4.041741 seconds
Current memory usage is 1.5234699249267578Mo; Peak was 1.6198930740356445Mo
replication factor = 1
Create Time: 4.086197 seconds
Current memory usage is 1.522751808166504Mo; Peak was 1.6377840042114258Mo
Read Time: 0.008586 seconds
Queried 37 records
Current memory usage is 0.05591297149658203Mo; Peak was 0.11327362060546875Mo
replication factor = 1
Create Time: 4.096891 seconds
Current memory usage is 1.485137939453125Mo; Peak was 1.6207246780395508Mo
```

```
Read Time: 0.008519 seconds
Queried 37 records
Current memory usage is 0.05505847930908203Mo; Peak was 0.11241912841796875Mo
replication factor = 1
Create Time: 4.089685 seconds
Current memory usage is 1.468867301940918Mo; Peak was 1.6245613098144531Mo
Read Time: 0.008513 seconds
Queried 37 records
Current memory usage is 0.05345630645751953Mo; Peak was 0.11132049560546875Mo
replication factor = 1
Create Time: 4.043645 seconds
Current memory usage is 1.460495948791504Mo; Peak was 1.6161670684814453Mo
Read Time: 0.008405 seconds
Queried 37 records
Current memory usage is 0.05394077301025390 6Mo; Peak was 0.11180496215820312Mo
replication factor = 1
Create Time: 4.107491 seconds
Current memory usage is 1.4395294189453125Mo; Peak was 1.6219873428344727Mo
Read Time: 0.008505 seconds
Queried 37 records
Current memory usage is 0.05216693878173828Mo; Peak was 0.1105194091796875Mo
replication factor = 1
Create Time: 4.056376 seconds
Current memory usage is 1.4868860244750977Mo; Peak was 1.6196403503417969Mo
Update Time: 0.022308 seconds
Current memory usage is 0.07096099853515625Mo; Peak was 0.10373497009277344Mo
replication factor = 1
Create Time: 4.027028 seconds
Current memory usage is 1.488739013671875Mo; Peak was 1.6084785461425781Mo
Update Time: 0.021173 seconds
Current memory usage is 0.0813741683959961Mo; Peak was 0.09201335906982422Mo
replication factor = 1
Create Time: 4.120912 seconds
Current memory usage is 1.4922189712524414Mo; Peak was 1.6121759414672852Mo
Update Time: 0.022594 seconds
Current memory usage is 0.0808706283569336Mo; Peak was 0.09100627899169922Mo
replication factor = 1
Create Time: 4.360281 seconds
Current memory usage is 1.6368961334228516Mo; Peak was 1.6606903076171875Mo
Update Time: 0.022826 seconds
Current memory usage is 0.05805683135986328Mo; Peak was 0.13082599639892578Mo
replication factor = 1
Create Time: 4.047273 seconds
Current memory usage is 1.5846281051635742Mo; Peak was 1.6042957305908203Mo
Update Time: 0.023067 seconds
Current memory usage is 0.05802631378173828Mo; Peak was 0.12978839874267578Mo
replication factor = 1
Create Time: 4.113372 seconds
```

```
Current memory usage is 1.5876150131225586Mo; Peak was 1.6068058013916016Mo
Delete Time: 0.022722 seconds
Current memory usage is 0.05251312255859375Mo; Peak was 0.12453079223632812Mo
replication factor = 1
Create Time: 4.082411 seconds
Current memory usage is 1.5875139236450195Mo; Peak was 1.6083793640136719Mo
Delete Time: 0.022946 seconds
Current memory usage is 0.053206443786621094Mo; Peak was 0.12602615356445312Mo
replication factor = 1
Create Time: 4.006492 seconds
Current memory usage is 1.5844058990478516Mo; Peak was 1.604020118713379Mo
Delete Time: 0.023075 seconds
Current memory usage is 0.05396270751953125Mo; Peak was 0.12574005126953125Mo
replication factor = 1
Create Time: 4.087704 seconds
Current memory usage is 1.5997314453125Mo; Peak was 1.6104249954223633Mo
Delete Time: 0.022743 seconds
Current memory usage is 0.055419921875Mo; Peak was 0.12211132049560547Mo
replication factor = 1
Create Time: 4.110799 seconds
Current memory usage is 1.6062240600585938Mo; Peak was 1.6115942001342773Mo
Delete Time: 0.021729 seconds
Current memory usage is 0.059093475341796875Mo; Peak was 0.1187448501586914Mo
```

2.5.3 Visualisation

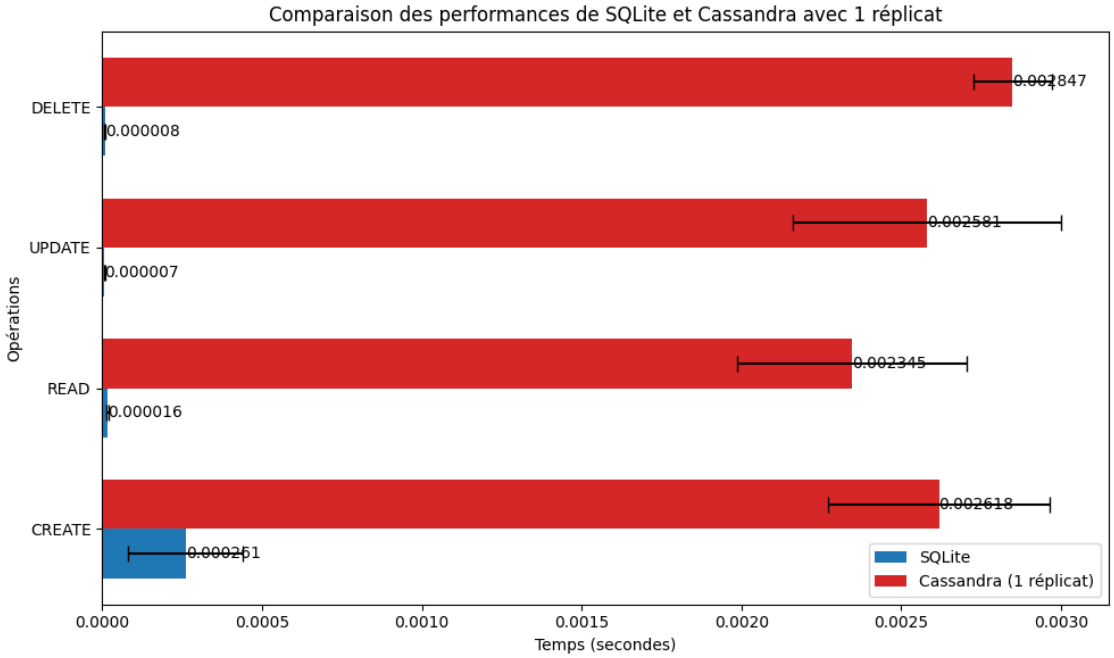
Nous avons d'abord testé avec un seul replicaSet et sans index, en insérant une seule ligne de données pour simplifier les tests.

Ensuite, pour obtenir des statistiques plus réalistes, nous avons effectué des opérations CRUD sur un volume de données plus important, en utilisant les données de Kaggle précédemment chargées.

Chaque action (insertion, lecture, mise à jour, suppression) a été réalisée cinq fois, et nous avons calculé la moyenne et l'écart-type pour chaque opération afin d'effectuer un benchmarking précis.

[22]:
```
# Valeurs de temps pour SQLite
sqlite_times = {
    'CREATE': (create_sqlite_simple_mean_time, create_sqlite_simple_std_time),
    'READ': (read_sqlite_simple_mean_time, read_sqlite_simple_std_time),
    'UPDATE': (update_sqlite_simple_mean_time, update_sqlite_simple_std_time),
    'DELETE': (delete_sqlite_simple_mean_time, delete_sqlite_simple_std_time)
}

# Valeurs de temps pour Cassandra avec 1 réplicat
cassandra_times = {
    'CREATE': (create_cassandra_simple_mean_time,␣
 ↪create_cassandra_simple_std_time),
    'READ': (read_cassandra_simple_mean_time, read_cassandra_simple_std_time),
```

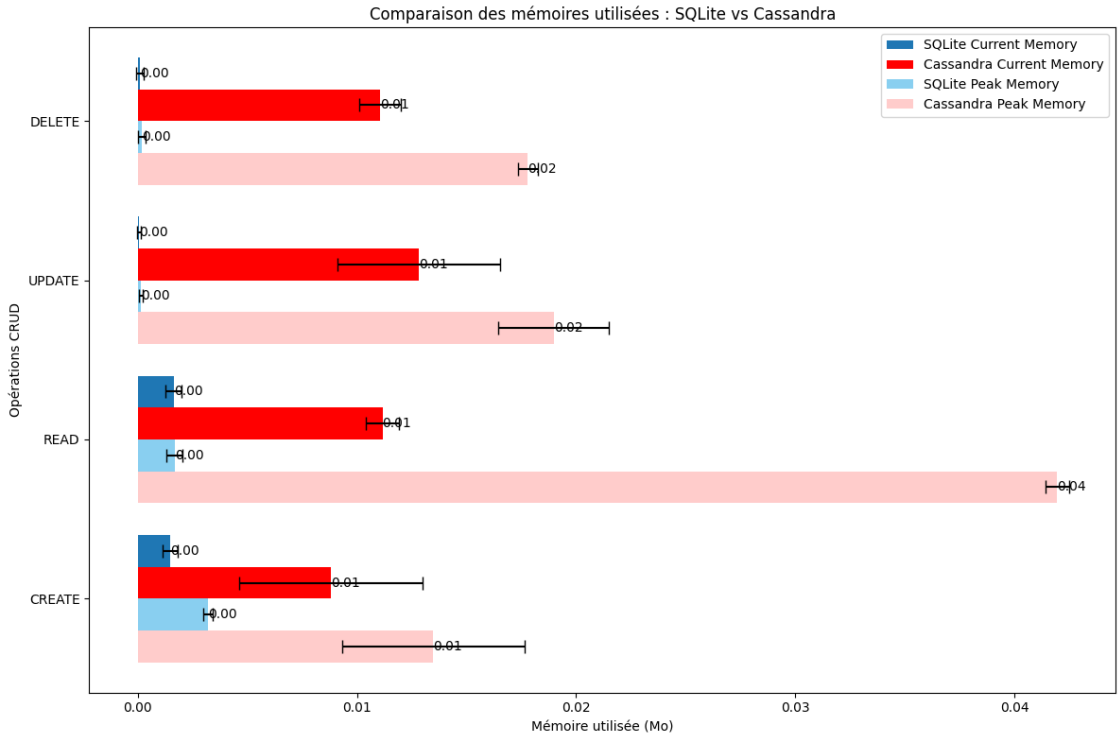
```
    'UPDATE': (update_cassandra_simple_mean_time,␣
 ↪update_cassandra_simple_std_time),
    'DELETE': (delete_cassandra_simple_mean_time,␣
 ↪delete_cassandra_simple_std_time)
}

operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

sqlite_means = [sqlite_times[op][0] for op in operations]
sqlite_stds = [sqlite_times[op][1] for op in operations]

cassandra_means = [cassandra_times[op][0] for op in operations]
cassandra_stds = [cassandra_times[op][1] for op in operations]

y = np.arange(len(operations))
height = 0.35
fig, ax = plt.subplots(figsize=(10, 6))

bars1 = ax.barh(y - height / 2, sqlite_means, height, xerr=sqlite_stds,␣
 ↪label='SQLite', capsize=5, color='tab:blue')
bars2 = ax.barh(y + height / 2, cassandra_means, height, xerr=cassandra_stds,␣
 ↪label='Cassandra (1 réplicat)', capsize=5, color='tab:red')

ax.set_xlabel('Temps (secondes)')
ax.set_ylabel('Opérations')
ax.set_title('Comparaison des performances de SQLite et Cassandra avec 1␣
 ↪réplicat')
ax.set_yticks(y)
ax.set_yticklabels(operations)
ax.legend()

def add_values(bars):
    for bar in bars:
        xval = bar.get_width()
        ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
 ↪va='center', ha='left')

add_values(bars1)
add_values(bars2)

plt.tight_layout()
plt.show()
```



[23]:
```
sqlite_memory = {
    'CREATE': {'current': (create_sqlite_simple_mean_current_memory,␣
 ↪create_sqlite_simple_std_current_memory),
               'peak': (create_sqlite_simple_mean_peak_memory,␣
 ↪create_sqlite_simple_std_peak_memory)},
    'READ': {'current': (read_sqlite_simple_mean_current_memory,␣
 ↪read_sqlite_simple_std_current_memory),
             'peak': (read_sqlite_simple_mean_peak_memory,␣
 ↪read_sqlite_simple_std_peak_memory)},
    'UPDATE': {'current': (update_sqlite_simple_mean_current_memory,␣
 ↪update_sqlite_simple_std_current_memory),
               'peak': (update_sqlite_simple_mean_peak_memory,␣
 ↪update_sqlite_simple_std_peak_memory)},
    'DELETE': {'current': (delete_sqlite_simple_mean_current_memory,␣
 ↪delete_sqlite_simple_std_current_memory),
               'peak': (delete_sqlite_simple_mean_peak_memory,␣
 ↪delete_sqlite_simple_std_peak_memory)}
}

cassandra_memory = {
    'CREATE': {'current': (create_cassandra_simple_mean_current_memory,␣
 ↪create_cassandra_simple_std_current_memory),
               'peak': (create_cassandra_simple_mean_peak_memory,␣
 ↪create_cassandra_simple_std_peak_memory)},
```

```
    'READ': {'current': (read_cassandra_simple_mean_current_memory,␣
 ↪read_cassandra_simple_std_current_memory),
             'peak': (read_cassandra_simple_mean_peak_memory,␣
 ↪read_cassandra_simple_std_peak_memory)},
    'UPDATE': {'current': (update_cassandra_simple_mean_current_memory,␣
 ↪update_cassandra_simple_std_current_memory),
               'peak': (update_cassandra_simple_mean_peak_memory,␣
 ↪update_cassandra_simple_std_peak_memory)},
    'DELETE': {'current': (delete_cassandra_simple_mean_current_memory,␣
 ↪delete_cassandra_simple_std_current_memory),
               'peak': (delete_cassandra_simple_mean_peak_memory,␣
 ↪delete_cassandra_simple_std_peak_memory)}
}

operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

sqlite_current_means = [sqlite_memory[op]['current'][0] for op in operations]
sqlite_current_stds = [sqlite_memory[op]['current'][1] for op in operations]
sqlite_peak_means = [sqlite_memory[op]['peak'][0] for op in operations]
sqlite_peak_stds = [sqlite_memory[op]['peak'][1] for op in operations]

cassandra_current_means = [cassandra_memory[op]['current'][0] for op in␣
 ↪operations]
cassandra_current_stds = [cassandra_memory[op]['current'][1] for op in␣
 ↪operations]
cassandra_peak_means = [cassandra_memory[op]['peak'][0] for op in operations]
cassandra_peak_stds = [cassandra_memory[op]['peak'][1] for op in operations]

y = np.arange(len(operations))
height = 0.2

fig, ax = plt.subplots(figsize=(12, 8))

bars_sqlite_current = ax.barh(y + 1.5 * height, sqlite_current_means, height,
                              xerr=sqlite_current_stds, label='SQLite Current␣
 ↪Memory', color='tab:blue', capsize=5)
bars_cassandra_current = ax.barh(y + 0.5 * height, cassandra_current_means,␣
 ↪height,
                                 xerr=cassandra_current_stds, label='Cassandra␣
 ↪Current Memory', color='red', capsize=5)
bars_sqlite_peak = ax.barh(y - 0.5 * height, sqlite_peak_means, height,
                           xerr=sqlite_peak_stds, label='SQLite Peak Memory',␣
 ↪color='#89CFF0', capsize=5) # bleu clair
bars_cassandra_peak = ax.barh(y - 1.5 * height, cassandra_peak_means, height,
                              xerr=cassandra_peak_stds, label='Cassandra Peak␣
 ↪Memory', color='#FFCCCB', capsize=5) # rouge clair
```

```
ax.set_xlabel('Mémoire utilisée (Mo)')
ax.set_ylabel('Opérations CRUD')
ax.set_title('Comparaison des mémoires utilisées : SQLite vs Cassandra')
ax.set_yticks(y)
ax.set_yticklabels(operations)
ax.legend()

def add_values(bars):
    for bar in bars:
        xval = bar.get_width()
        ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.2f}',␣
 ↪va='center', ha='left')

add_values(bars_sqlite_current)
add_values(bars_cassandra_current)
add_values(bars_sqlite_peak)
add_values(bars_cassandra_peak)

plt.tight_layout()
plt.show()
```



En testant SQLite et Cassandra avec une seule ligne de données et une réplication pour Cassandra, on remarque des différences claires :

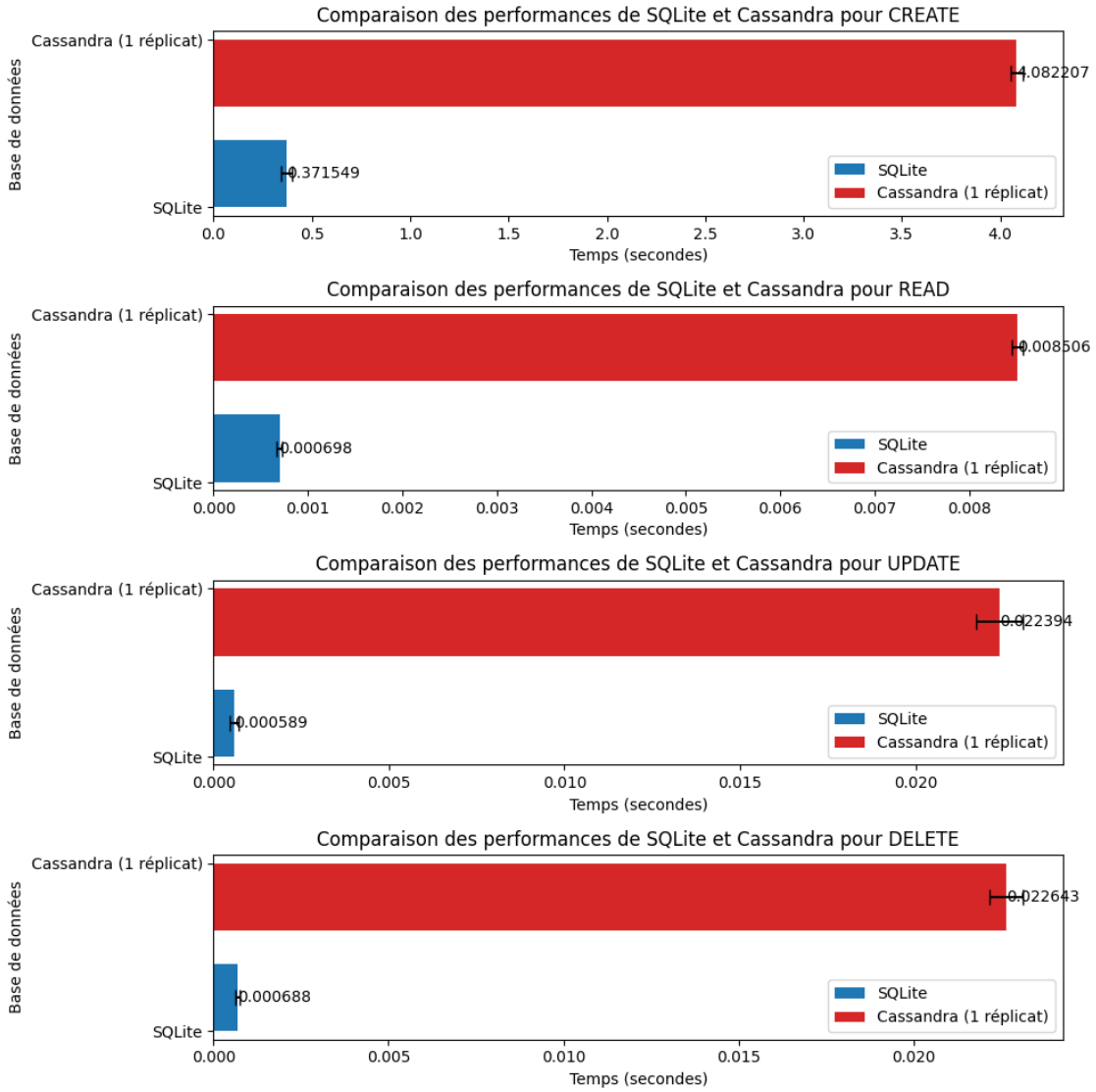
- **SQLite** :
  Ici, l'opération la plus lente est la création de la ligne de données. En revanche, les lectures, mises à jour et suppressions sont rapides, ce qui montre que SQLite est bien optimisé pour des petits volumes de données.
- **Cassandra** :
  La lecture est l'opération la plus rapide, ce qui correspond bien à la manière dont Cassandra est conçu pour gérer les requêtes en lecture.
  Les mises à jour et suppressions prennent à peu près le même temps, et sont un peu plus rapides que la création.
  La création, par contre, est la plus lente, probablement à cause de la gestion de la réplication et des contraintes liées à son architecture distribuée.

On fait le même constat concernant la mémoire (current et peak), où Cassandra est beaucoup plus gourmand que SQLite, notamment avec un pic énorme en lecture pour Cassandra.

Globalement, avec une seule ligne de données, Cassandra est beaucoup plus lent que SQLite. Cela s'explique par son architecture distribuée, qui ajoute un overhead même dans des contextes simples, et par ses mécanismes de réplication et de gestion des partitions, conçus pour des scénarios à grande échelle. En revanche, SQLite, étant une solution locale et légère, est optimisé pour des opérations rapides sur de petites bases de données.

[24]:
```
# Données des temps de SQLite et Cassandra pour chaque opération
sqlite_times = {
    'CREATE': (create_sqlite_initial_mean_time, create_sqlite_initial_std_time),
    'READ': (read_sqlite_initial_mean_time, read_sqlite_initial_std_time),
    'UPDATE': (update_sqlite_initial_mean_time, update_sqlite_initial_std_time),
    'DELETE': (delete_sqlite_initial_mean_time, delete_sqlite_initial_std_time)
}

cassandra_times = {
    'CREATE': (create_cassandra_initial_mean_time,␣
 ↪create_cassandra_initial_std_time),
    'READ': (read_cassandra_initial_mean_time, read_cassandra_initial_std_time),
    'UPDATE': (update_cassandra_initial_mean_time,␣
 ↪update_cassandra_initial_std_time),
    'DELETE': (delete_cassandra_initial_mean_time,␣
 ↪delete_cassandra_initial_std_time)
}

operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

sqlite_means = [sqlite_times[op][0] for op in operations]
sqlite_stds = [sqlite_times[op][1] for op in operations]

cassandra_means = [cassandra_times[op][0] for op in operations]
cassandra_stds = [cassandra_times[op][1] for op in operations]

fig, axes = plt.subplots(4, 1, figsize=(10, 10))
```

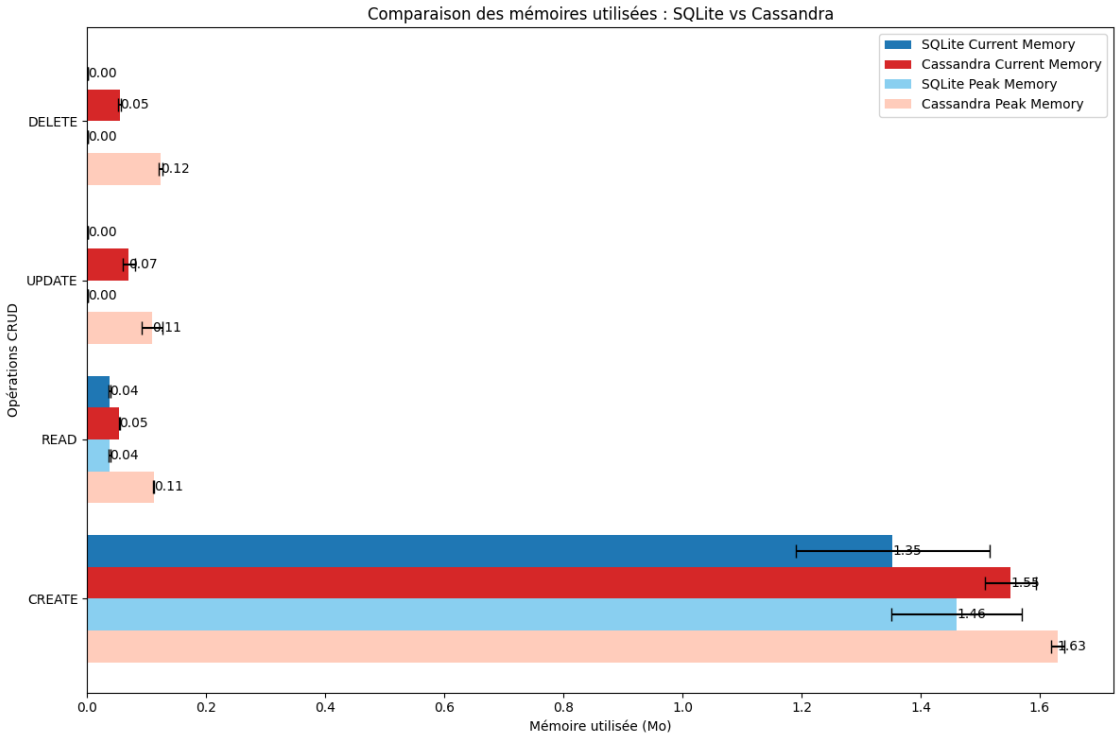
```
height = 0.4

for i, op in enumerate(operations):
    ax = axes[i]
    y = np.arange(2)

    bars1 = ax.barh(y[0] + height / 2, sqlite_times[op][0], height,␣
 ↪xerr=sqlite_times[op][1], label='SQLite', capsize=5, color='tab:blue')
    bars2 = ax.barh(y[1] - height / 2, cassandra_times[op][0], height,␣
 ↪xerr=cassandra_times[op][1], label='Cassandra (1 réplicat)', capsize=5,␣
 ↪color='tab:red')

    ax.set_xlabel('Temps (secondes)')
    ax.set_ylabel('Base de données')
    ax.set_title(f'Comparaison des performances de SQLite et Cassandra pour␣
 ↪{op}')
    ax.set_yticks(y)
    ax.set_yticklabels(['SQLite', 'Cassandra (1 réplicat)'])
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
 ↪va='center', ha='left')

    add_values(bars1)
    add_values(bars2)

plt.tight_layout()
plt.show()
```



[25]:
```
# Valeurs de mémoire pour SQLite (current et peak)
sqlite_memory = {
    'CREATE': {'current': (create_sqlite_initial_mean_current_memory,␣
 ↪create_sqlite_initial_std_current_memory),
               'peak': (create_sqlite_initial_mean_peak_memory,␣
 ↪create_sqlite_initial_std_peak_memory)},
    'READ': {'current': (read_sqlite_initial_mean_current_memory,␣
 ↪read_sqlite_initial_std_current_memory),
             'peak': (read_sqlite_initial_mean_peak_memory,␣
 ↪read_sqlite_initial_std_peak_memory)},
    'UPDATE': {'current': (update_sqlite_initial_mean_current_memory,␣
 ↪update_sqlite_initial_std_current_memory),
```

```
                'peak': (update_sqlite_initial_mean_peak_memory,␣
 ↪update_sqlite_initial_std_peak_memory)},
    'DELETE': {'current': (delete_sqlite_initial_mean_current_memory,␣
 ↪delete_sqlite_initial_std_current_memory),
                'peak': (delete_sqlite_initial_mean_peak_memory,␣
 ↪delete_sqlite_initial_std_peak_memory)}
}

# Valeurs de mémoire pour Cassandra (current et peak)
cassandra_memory = {
    'CREATE': {'current': (create_cassandra_initial_mean_current_memory,␣
 ↪create_cassandra_initial_std_current_memory),
                'peak': (create_cassandra_initial_mean_peak_memory,␣
 ↪create_cassandra_initial_std_peak_memory)},
    'READ': {'current': (read_cassandra_initial_mean_current_memory,␣
 ↪read_cassandra_initial_std_current_memory),
             'peak': (read_cassandra_initial_mean_peak_memory,␣
 ↪read_cassandra_initial_std_peak_memory)},
    'UPDATE': {'current': (update_cassandra_initial_mean_current_memory,␣
 ↪update_cassandra_initial_std_current_memory),
                'peak': (update_cassandra_initial_mean_peak_memory,␣
 ↪update_cassandra_initial_std_peak_memory)},
    'DELETE': {'current': (delete_cassandra_initial_mean_current_memory,␣
 ↪delete_cassandra_initial_std_current_memory),
                'peak': (delete_cassandra_initial_mean_peak_memory,␣
 ↪delete_cassandra_initial_std_peak_memory)}
}

operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

sqlite_current_means = [sqlite_memory[op]['current'][0] for op in operations]
sqlite_current_stds = [sqlite_memory[op]['current'][1] for op in operations]
sqlite_peak_means = [sqlite_memory[op]['peak'][0] for op in operations]
sqlite_peak_stds = [sqlite_memory[op]['peak'][1] for op in operations]

cassandra_current_means = [cassandra_memory[op]['current'][0] for op in␣
 ↪operations]
cassandra_current_stds = [cassandra_memory[op]['current'][1] for op in␣
 ↪operations]
cassandra_peak_means = [cassandra_memory[op]['peak'][0] for op in operations]
cassandra_peak_stds = [cassandra_memory[op]['peak'][1] for op in operations]

y = np.arange(len(operations))
height = 0.2

fig, ax = plt.subplots(figsize=(12, 8))
```

```
bars_sqlite_current = ax.barh(y + 1.5 * height, sqlite_current_means, height,
                              xerr=sqlite_current_stds, label='SQLite Current␣
 ↪Memory', color='tab:blue', capsize=5)
bars_cassandra_current = ax.barh(y + 0.5 * height, cassandra_current_means,␣
 ↪height,
                                 xerr=cassandra_current_stds, label='Cassandra␣
 ↪Current Memory', color='tab:red', capsize=5)
bars_sqlite_peak = ax.barh(y - 0.5 * height, sqlite_peak_means, height,
                           xerr=sqlite_peak_stds, label='SQLite Peak Memory',␣
 ↪color='#89CFF0', capsize=5)
bars_cassandra_peak = ax.barh(y - 1.5 * height, cassandra_peak_means, height,
                              xerr=cassandra_peak_stds, label='Cassandra Peak␣
 ↪Memory', color='#FFCCBB', capsize=5)

ax.set_xlabel('Mémoire utilisée (Mo)')
ax.set_ylabel('Opérations CRUD')
ax.set_title('Comparaison des mémoires utilisées : SQLite vs Cassandra')
ax.set_yticks(y)
ax.set_yticklabels(operations)
ax.legend()

def add_values(bars):
    for bar in bars:
        xval = bar.get_width()
        ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.2f}',␣
 ↪va='center', ha='left')

add_values(bars_sqlite_current)
add_values(bars_cassandra_current)
add_values(bars_sqlite_peak)
add_values(bars_cassandra_peak)

plt.tight_layout()
plt.show()
```



En analysant les échelles de temps, plusieurs observations se dégagent : - Cassandra affiche systématiquement des temps d'exécution plus longs que SQLite, quelle que soit l'opération effectuée. - Pour les deux bases de données, l'opération CREATE est toujours la plus longue, tandis que READ est la plus rapide pour Cassandra. - Les temps des opérations UPDATE et DELETE sont comparables pour Cassandra. - Du côté de SQLite, les opérations UPDATE et DELETE consomment très peu de mémoire, tandis que READ est légèrement plus exigeante. - Cependant, SQLite utilise globalement davantage de mémoire (current et peak, entre 1.3 et 1.4 fois plus) pour l'ensemble des opérations. - Enfin, l'opération CREATE nécessite une quantité de mémoire similaire pour Cassandra et SQLite.

2.6 Comparaison des temps de Cassandra avec plusieurs replicaSet

NB : Qu'est ce que *SimpleStrategy* ? Description : Réplique les données de manière linéaire sur les n nœuds du cluster, où n est le replication_factor. - Avantages : - Simple à configurer. - Adapté aux environnements de test ou aux clusters d'une seule région. - Inconvénients : - Pas optimisé pour les déploiements multi-régions. - Répartition des réplicas pas toujours équilibrée en cas de cluster complexe.

[26]:
```
# 2 replicas
# --- CREATE ---
create_cassandra_initial_mean_time_2, create_cassandra_initial_std_time_2, \
    create_cassandra_initial_mean_current_memory_2,␣
 ↪create_cassandra_initial_std_current_memory_2, \
```

```
        create_cassandra_initial_mean_peak_memory_2,␣
 ↪create_cassandra_initial_std_peak_memory_2 =␣
 ↪benchmark_operation(cassandra_insert, df_initial, 2)

# --- READ ---
read_cassandra_initial_mean_time_2, read_cassandra_initial_std_time_2, \
    read_cassandra_initial_mean_current_memory_2,␣
 ↪read_cassandra_initial_std_current_memory_2, \
        read_cassandra_initial_mean_peak_memory_2,␣
 ↪read_cassandra_initial_std_peak_memory_2 =␣
 ↪benchmark_operation(cassandra_read, df_initial, 2)

# --- UPDATE ---
update_cassandra_initial_mean_time_2, update_cassandra_initial_std_time_2, \
    update_cassandra_initial_mean_current_memory_2,␣
 ↪update_cassandra_initial_std_current_memory_2, \
        update_cassandra_initial_mean_peak_memory_2,␣
 ↪update_cassandra_initial_std_peak_memory_2 =␣
 ↪benchmark_operation(cassandra_update, df_initial, 2)

# --- DELETE ---
delete_cassandra_initial_mean_time_2, delete_cassandra_initial_std_time_2, \
    delete_cassandra_initial_mean_current_memory_2,␣
 ↪delete_cassandra_initial_std_current_memory_2, \
        delete_cassandra_initial_mean_peak_memory_2,␣
 ↪delete_cassandra_initial_std_peak_memory_2 =␣
 ↪benchmark_operation(cassandra_delete, df_initial, 2)
```

```
replication factor = 2
Create Time: 4.068082 seconds
Current memory usage is 1.4770574569702148Mo; Peak was 1.6395702362060547Mo
replication factor = 2
Create Time: 4.106127 seconds
Current memory usage is 1.5557823181152344Mo; Peak was 1.624180793762207Mo
replication factor = 2
Create Time: 4.082963 seconds
Current memory usage is 1.5284862518310547Mo; Peak was 1.6379022598266602Mo
replication factor = 2
Create Time: 4.058528 seconds
Current memory usage is 1.4755449295043945Mo; Peak was 1.6221847534179688Mo
replication factor = 2
Create Time: 4.065082 seconds
Current memory usage is 1.5885238647460938Mo; Peak was 1.6352386474609375Mo
replication factor = 2
Create Time: 4.117278 seconds
Current memory usage is 1.5212888717651367Mo; Peak was 1.6217231750488281Mo
Read Time: 0.008584 seconds
```

```
Queried 37 records
Current memory usage is 0.057152748107910156Mo; Peak was 0.11367416381835938Mo
replication factor = 2
Create Time: 4.030853 seconds
Current memory usage is 1.5574464797973633Mo; Peak was 1.6182441711425781Mo
Read Time: 0.008594 seconds
Queried 37 records
Current memory usage is 0.056885719299316406Mo; Peak was 0.11367416381835938Mo
replication factor = 2
Create Time: 4.089470 seconds
Current memory usage is 1.5557060241699219Mo; Peak was 1.6207771301269531Mo
Read Time: 0.008513 seconds
Queried 37 records
Current memory usage is 0.056885719299316406Mo; Peak was 0.11367416381835938Mo
replication factor = 2
Create Time: 4.127382 seconds
Current memory usage is 1.5732412338256836Mo; Peak was 1.6240310668945312Mo
Read Time: 0.008482 seconds
Queried 37 records
Current memory usage is 0.05631351470947266Mo; Peak was 0.11367416381835938Mo
replication factor = 2
Create Time: 4.018906 seconds
Current memory usage is 1.5826520919799805Mo; Peak was 1.6252326965332031Mo
Read Time: 0.008700 seconds
Queried 37 records
Current memory usage is 0.05590915679931641Mo; Peak was 0.11367416381835938Mo
replication factor = 2
Create Time: 4.081511 seconds
Current memory usage is 1.5583715438842773Mo; Peak was 1.6225872039794922Mo
Update Time: 0.023003 seconds
Current memory usage is 0.044811248779296875Mo; Peak was 0.1415691375732422Mo
replication factor = 2
Create Time: 4.088963 seconds
Current memory usage is 1.563084602355957Mo; Peak was 1.6151151657104492Mo
Update Time: 0.022973 seconds
Current memory usage is 0.05063056945800781Mo; Peak was 0.14020919799804688Mo
replication factor = 2
Create Time: 4.048554 seconds
Current memory usage is 1.5612468719482422Mo; Peak was 1.6138076782226562Mo
Update Time: 0.022831 seconds
Current memory usage is 0.05113410949707031Mo; Peak was 0.14071273803710938Mo
replication factor = 2
Create Time: 4.088597 seconds
Current memory usage is 1.5721702575683594Mo; Peak was 1.6141633987426758Mo
Update Time: 0.022680 seconds
Current memory usage is 0.05101776123046875Mo; Peak was 0.12999916076660156Mo
replication factor = 2
Create Time: 4.083769 seconds
```

```
Current memory usage is 1.5697546005249023Mo; Peak was 1.6127815246582031Mo
Update Time: 0.022723 seconds
Current memory usage is 0.05126190185546875Mo; Peak was 0.1305866241455078Mo
replication factor = 2
Create Time: 4.043080 seconds
Current memory usage is 1.5856151580810547Mo; Peak was 1.6136503219604492Mo
Delete Time: 0.022446 seconds
Current memory usage is 0.054294586181640625Mo; Peak was 0.12566757202148438Mo
replication factor = 2
Create Time: 4.134338 seconds
Current memory usage is 1.5903091430664062Mo; Peak was 1.6145439147949219Mo
Delete Time: 0.022770 seconds
Current memory usage is 0.05475807189941406Mo; Peak was 0.12364768981933594Mo
replication factor = 2
Create Time: 4.095154 seconds
Current memory usage is 1.5967445373535156Mo; Peak was 1.6158018112182617Mo
Delete Time: 0.022550 seconds
Current memory usage is 0.056915283203125Mo; Peak was 0.11914443969726562Mo
replication factor = 2
Create Time: 4.140479 seconds
Current memory usage is 1.4870185852050781Mo; Peak was 1.6307334899902344Mo
Delete Time: 0.022133 seconds
Current memory usage is 0.06926155090332031Mo; Peak was 0.10053825378417969Mo
replication factor = 2
Create Time: 4.102423 seconds
Current memory usage is 1.4860191345214844Mo; Peak was 1.6145210266113281Mo
Delete Time: 0.022172 seconds
Current memory usage is 0.08448028564453125Mo; Peak was 0.08823871612548828Mo
```

[27]:

```
# 5 replicas
# --- CREATE ---
create_cassandra_initial_mean_time_5, create_cassandra_initial_std_time_5, \
    create_cassandra_initial_mean_current_memory_5,␣
 ↪create_cassandra_initial_std_current_memory_5, \
       create_cassandra_initial_mean_peak_memory_5,␣
 ↪create_cassandra_initial_std_peak_memory_5 =␣
 ↪benchmark_operation(cassandra_insert, df_initial, 5)

# --- READ ---
read_cassandra_initial_mean_time_5, read_cassandra_initial_std_time_5, \
    read_cassandra_initial_mean_current_memory_5,␣
 ↪read_cassandra_initial_std_current_memory_5, \
       read_cassandra_initial_mean_peak_memory_5,␣
 ↪read_cassandra_initial_std_peak_memory_5 =␣
 ↪benchmark_operation(cassandra_read, df_initial, 5)

# --- UPDATE ---
```

```
update_cassandra_initial_mean_time_5, update_cassandra_initial_std_time_5, \
    update_cassandra_initial_mean_current_memory_5,␣
 ↪update_cassandra_initial_std_current_memory_5, \
       update_cassandra_initial_mean_peak_memory_5,␣
 ↪update_cassandra_initial_std_peak_memory_5 =␣
 ↪benchmark_operation(cassandra_update, df_initial, 5)

# --- DELETE ---
delete_cassandra_initial_mean_time_5, delete_cassandra_initial_std_time_5, \
    delete_cassandra_initial_mean_current_memory_5,␣
 ↪delete_cassandra_initial_std_current_memory_5, \
       delete_cassandra_initial_mean_peak_memory_5,␣
 ↪delete_cassandra_initial_std_peak_memory_5 =␣
 ↪benchmark_operation(cassandra_delete, df_initial, 5)
```

```
replication factor = 5
Create Time: 4.089206 seconds
Current memory usage is 1.5372400283813477Mo; Peak was 1.6212406158447266Mo
replication factor = 5
Create Time: 4.057425 seconds
Current memory usage is 1.4885272979736328Mo; Peak was 1.6206951141357422Mo
replication factor = 5
Create Time: 4.065723 seconds
Current memory usage is 1.5893497467041016Mo; Peak was 1.6230649948120117Mo
replication factor = 5
Create Time: 4.094151 seconds
Current memory usage is 1.5361146926879883Mo; Peak was 1.6233940124511719Mo
replication factor = 5
Create Time: 4.074848 seconds
Current memory usage is 1.493514060974121Mo; Peak was 1.6210756301879883Mo
replication factor = 5
Create Time: 4.034785 seconds
Current memory usage is 1.4582176208496094Mo; Peak was 1.6162748336791992Mo
Read Time: 0.008552 seconds
Queried 37 records
Current memory usage is 0.05286884307861328Mo; Peak was 0.1107330322265625Mo
replication factor = 5
Create Time: 4.139573 seconds
Current memory usage is 1.4490842819213867Mo; Peak was 1.622396469116211Mo
Read Time: 0.008657 seconds
Queried 37 records
Current memory usage is 0.05219364166259766Mo; Peak was 0.11054611206054688Mo
replication factor = 5
Create Time: 4.089897 seconds
Current memory usage is 1.4343976974487305Mo; Peak was 1.6234722137451172Mo
Read Time: 0.008501 seconds
Queried 37 records
```

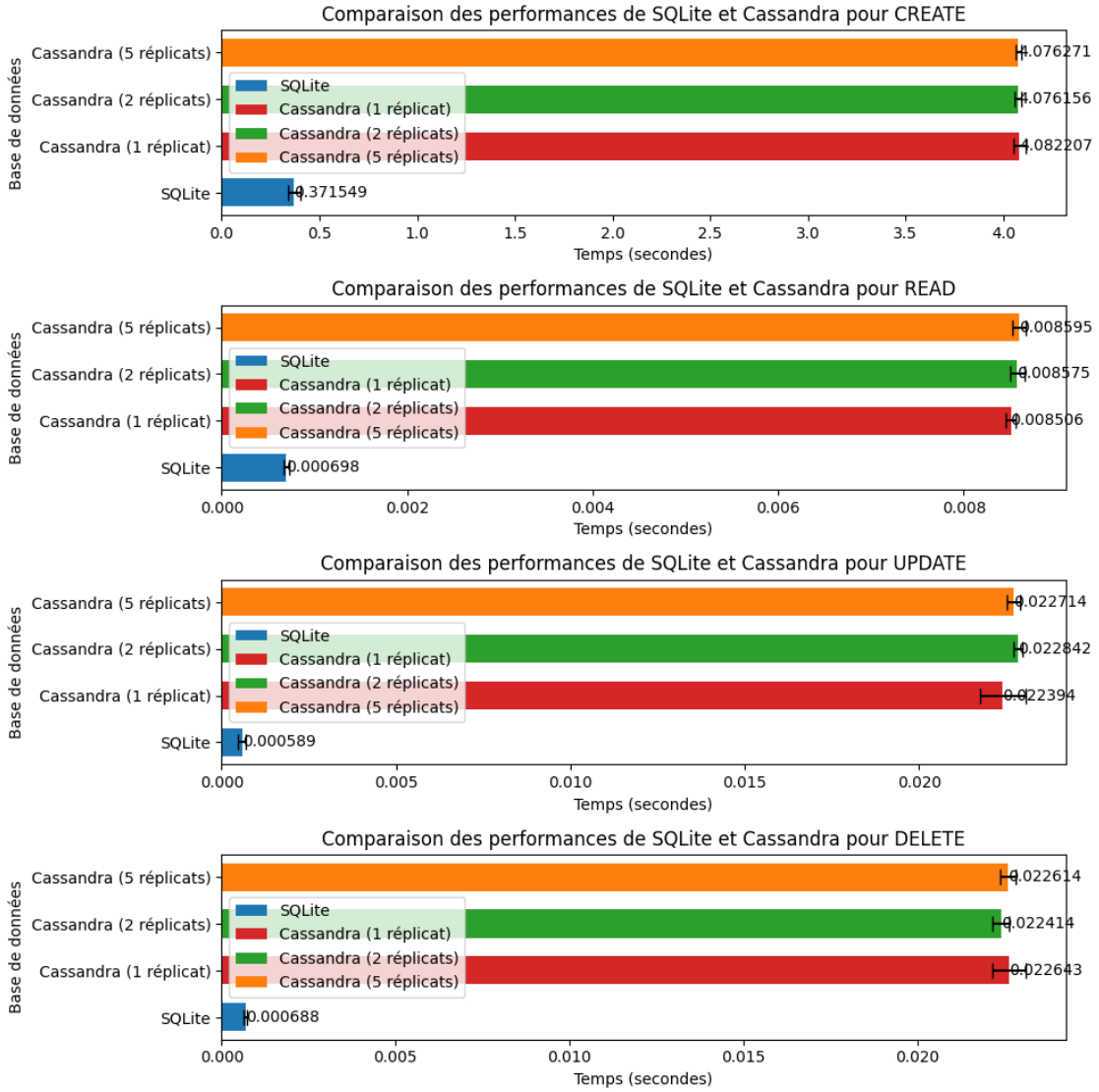
```
Current memory usage is 0.05219364166259765Mo; Peak was 0.11054611206054688Mo
replication factor = 5
Create Time: 4.065206 seconds
Current memory usage is 1.5950212478637695Mo; Peak was 1.6157798767089844Mo
Read Time: 0.008694 seconds
Queried 37 records
Current memory usage is 0.052964210510253906Mo; Peak was 0.1131134033203125Mo
replication factor = 5
Create Time: 4.079222 seconds
Current memory usage is 1.5908899307250977Mo; Peak was 1.637833595275879Mo
Read Time: 0.008569 seconds
Queried 37 records
Current memory usage is 0.056885719299316406Mo; Peak was 0.11367416381835938Mo
replication factor = 5
Create Time: 4.093428 seconds
Current memory usage is 1.561635971069336Mo; Peak was 1.6272830963134766Mo
Update Time: 0.022672 seconds
Current memory usage is 0.041327476501464844Mo; Peak was 0.14182758331298828Mo
replication factor = 5
Create Time: 4.048495 seconds
Current memory usage is 1.5589075088500977Mo; Peak was 1.6148557662963867Mo
Update Time: 0.023058 seconds
Current memory usage is 0.044574737548828125Mo; Peak was 0.13914966583251953Mo
replication factor = 5
Create Time: 4.071497 seconds
Current memory usage is 1.5723581314086914Mo; Peak was 1.6146183013916016Mo
Update Time: 0.022719 seconds
Current memory usage is 0.04852581024169922Mo; Peak was 0.1352376937866211Mo
replication factor = 5
Create Time: 4.155663 seconds
Current memory usage is 1.4532794952392578Mo; Peak was 1.6007394790649414Mo
Update Time: 0.022609 seconds
Current memory usage is 0.0795278549194336Mo; Peak was 0.10938167572021484Mo
replication factor = 5
Create Time: 4.069447 seconds
Current memory usage is 1.488539695739746Mo; Peak was 1.616511344909668Mo
Update Time: 0.022511 seconds
Current memory usage is 0.08420944213867188Mo; Peak was 0.08894729614257812Mo
replication factor = 5
Create Time: 4.054014 seconds
Current memory usage is 1.5115652084350586Mo; Peak was 1.6212635040283203Mo
Delete Time: 0.022507 seconds
Current memory usage is 0.10109615325927734Mo; Peak was 0.10483551025390625Mo
replication factor = 5
Create Time: 4.095008 seconds
Current memory usage is 1.536595344543457Mo; Peak was 1.615300178527832Mo
Delete Time: 0.022407 seconds
Current memory usage is 0.12987136840820312Mo; Peak was 0.13361072540283203Mo
```

```
replication factor = 5
Create Time: 4.085694 seconds
Current memory usage is 1.5496187210083008Mo; Peak was 1.6198978424072266Mo
Delete Time: 0.022471 seconds
Current memory usage is 0.036431312561035156Mo; Peak was 0.13911151885986328Mo
replication factor = 5
Create Time: 4.100588 seconds
Current memory usage is 1.575648307800293Mo; Peak was 1.6234254837036133Mo
Delete Time: 0.023006 seconds
Current memory usage is 0.05260753631591797Mo; Peak was 0.14129257202148438Mo
replication factor = 5
Create Time: 4.080859 seconds
Current memory usage is 1.5960931777954102Mo; Peak was 1.6164674758911133Mo
Delete Time: 0.022678 seconds
Current memory usage is 0.05170440673828125Mo; Peak was 0.12009048461914062Mo
```

[28]:
```
# Données des temps pour SQLite et Cassandra
sqlite_times = {
    'CREATE': (create_sqlite_initial_mean_time, create_sqlite_initial_std_time),
    'READ': (read_sqlite_initial_mean_time, read_sqlite_initial_std_time),
    'UPDATE': (update_sqlite_initial_mean_time, update_sqlite_initial_std_time),
    'DELETE': (delete_sqlite_initial_mean_time, delete_sqlite_initial_std_time)
}

cassandra_times = {
    'CREATE': (create_cassandra_initial_mean_time,␣
 ↪create_cassandra_initial_std_time),
    'READ': (read_cassandra_initial_mean_time, read_cassandra_initial_std_time),
    'UPDATE': (update_cassandra_initial_mean_time,␣
 ↪update_cassandra_initial_std_time),
    'DELETE': (delete_cassandra_initial_mean_time,␣
 ↪delete_cassandra_initial_std_time)
}

cassandra_times_2 = {
    'CREATE': (create_cassandra_initial_mean_time_2,␣
 ↪create_cassandra_initial_std_time_2),
    'READ': (read_cassandra_initial_mean_time_2,␣
 ↪read_cassandra_initial_std_time_2),
    'UPDATE': (update_cassandra_initial_mean_time_2,␣
 ↪update_cassandra_initial_std_time_2),
    'DELETE': (delete_cassandra_initial_mean_time_2,␣
 ↪delete_cassandra_initial_std_time_2)
}

cassandra_times_5 = {
```

```
    'CREATE': (create_cassandra_initial_mean_time_5,␣
 ↪create_cassandra_initial_std_time_5),
    'READ': (read_cassandra_initial_mean_time_5,␣
 ↪read_cassandra_initial_std_time_5),
    'UPDATE': (update_cassandra_initial_mean_time_5,␣
 ↪update_cassandra_initial_std_time_5),
    'DELETE': (delete_cassandra_initial_mean_time_5,␣
 ↪delete_cassandra_initial_std_time_5)
}

operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

# Extraire les moyennes et les écarts-types pour chaque opération
sqlite_means = [sqlite_times[op][0] for op in operations]
sqlite_stds = [sqlite_times[op][1] for op in operations]

cassandra_means = [cassandra_times[op][0] for op in operations]
cassandra_stds = [cassandra_times[op][1] for op in operations]

cassandra_means_2 = [cassandra_times_2[op][0] for op in operations]
cassandra_stds_2 = [cassandra_times_2[op][1] for op in operations]

cassandra_means_5 = [cassandra_times_5[op][0] for op in operations]
cassandra_stds_5 = [cassandra_times_5[op][1] for op in operations]

# Créer un graphique pour chaque opération
fig, axes = plt.subplots(4, 1, figsize=(10, 10))  # 4 graphiques sous le même␣
 ↪format
height = 0.6

# Générer chaque sous-graphe pour chaque opération
for i, op in enumerate(operations):
    ax = axes[i]
    y = np.arange(4)  # Quatre barres par graphique : SQLite, Cassandra (1),␣
 ↪(2) et (5) réplicats

    # Dessiner les barres pour SQLite et Cassandra avec différents réplicats
    bars1 = ax.barh(y[0] , sqlite_times[op][0], height,␣
 ↪xerr=sqlite_times[op][1], label='SQLite', capsize=5, color='tab:blue')
    bars2 = ax.barh(y[1] , cassandra_times[op][0], height,␣
 ↪xerr=cassandra_times[op][1], label='Cassandra (1 réplicat)', capsize=5,␣
 ↪color='tab:red')
    bars3 = ax.barh(y[2], cassandra_times_2[op][0], height,␣
 ↪xerr=cassandra_times_2[op][1], label='Cassandra (2 réplicats)', capsize=5,␣
 ↪color='tab:green')
```

```
    bars4 = ax.barh(y[3], cassandra_times_5[op][0], height,␣
↪xerr=cassandra_times_5[op][1], label='Cassandra (5 réplicats)', capsize=5,␣
↪color='tab:orange')

    # Titre et labels
    ax.set_xlabel('Temps (secondes)')
    ax.set_ylabel('Base de données')
    ax.set_title(f'Comparaison des performances de SQLite et Cassandra pour␣
↪{op}')
    ax.set_yticks(y)
    ax.set_yticklabels(['SQLite', 'Cassandra (1 réplicat)', 'Cassandra (2␣
↪réplicats)', 'Cassandra (5 réplicats)'])
    ax.legend()

    # Ajouter les valeurs aux barres
    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
↪va='center', ha='left')

    add_values(bars1)
    add_values(bars2)
    add_values(bars3)
    add_values(bars4)

# Ajuster l'espacement entre les graphiques
plt.tight_layout()
plt.show()
```

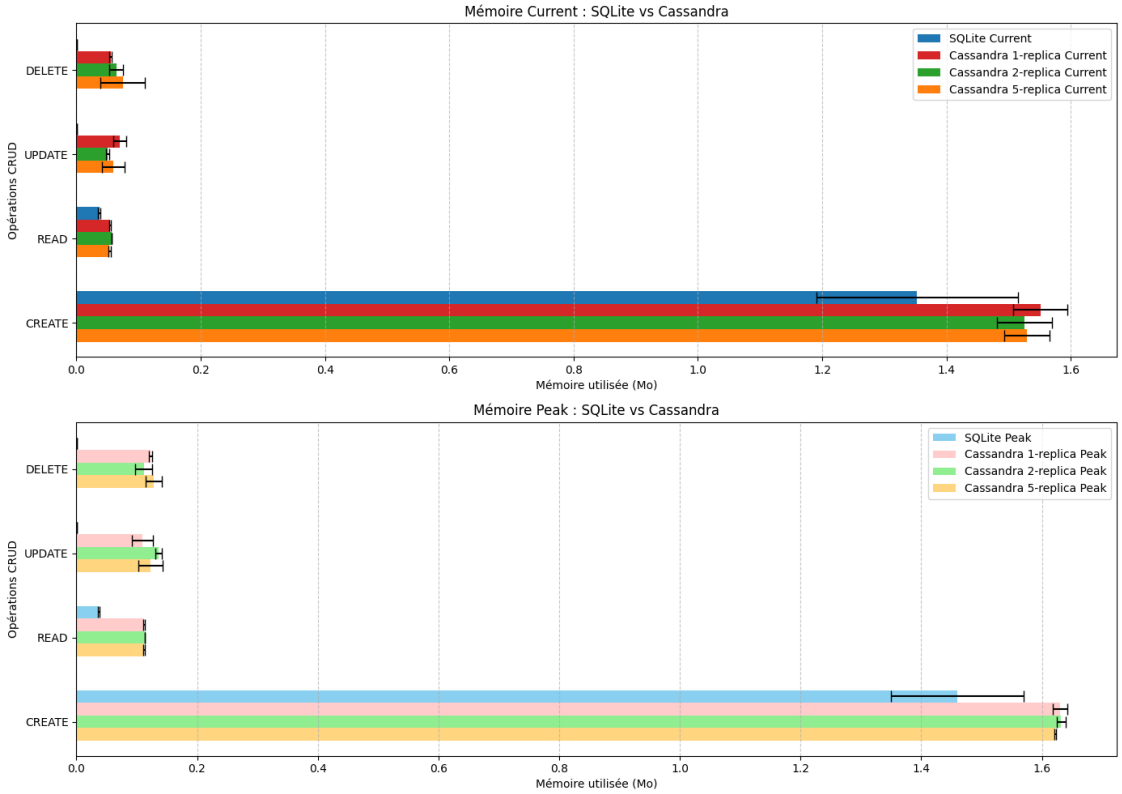


[29]:
```
# Valeurs de mémoire pour SQLite
sqlite_memory = {
    'CREATE': {'current': (create_sqlite_initial_mean_current_memory,␣
 ↪create_sqlite_initial_std_current_memory),
               'peak': (create_sqlite_initial_mean_peak_memory,␣
 ↪create_sqlite_initial_std_peak_memory)},
    'READ': {'current': (read_sqlite_initial_mean_current_memory,␣
 ↪read_sqlite_initial_std_current_memory),
             'peak': (read_sqlite_initial_mean_peak_memory,␣
 ↪read_sqlite_initial_std_peak_memory)},
    'UPDATE': {'current': (update_sqlite_initial_mean_current_memory,␣
 ↪update_sqlite_initial_std_current_memory),
```

```
                'peak': (update_sqlite_initial_mean_peak_memory,␣
 ↪update_sqlite_initial_std_peak_memory)},
    'DELETE': {'current': (delete_sqlite_initial_mean_current_memory,␣
 ↪delete_sqlite_initial_std_current_memory),
                'peak': (delete_sqlite_initial_mean_peak_memory,␣
 ↪delete_sqlite_initial_std_peak_memory)}
}

# Valeurs de mémoire pour Cassandra avec différentes réplications
cassandra_memory = {
    '1-replica': {
        'CREATE': {'current': (create_cassandra_initial_mean_current_memory,␣
 ↪create_cassandra_initial_std_current_memory),
                   'peak': (create_cassandra_initial_mean_peak_memory,␣
 ↪create_cassandra_initial_std_peak_memory)},
        'READ': {'current': (read_cassandra_initial_mean_current_memory,␣
 ↪read_cassandra_initial_std_current_memory),
                 'peak': (read_cassandra_initial_mean_peak_memory,␣
 ↪read_cassandra_initial_std_peak_memory)},
        'UPDATE': {'current': (update_cassandra_initial_mean_current_memory,␣
 ↪update_cassandra_initial_std_current_memory),
                   'peak': (update_cassandra_initial_mean_peak_memory,␣
 ↪update_cassandra_initial_std_peak_memory)},
        'DELETE': {'current': (delete_cassandra_initial_mean_current_memory,␣
 ↪delete_cassandra_initial_std_current_memory),
                   'peak': (delete_cassandra_initial_mean_peak_memory,␣
 ↪delete_cassandra_initial_std_peak_memory)}
    },
    '2-replica': {
        'CREATE': {'current': (create_cassandra_initial_mean_current_memory_2,␣
 ↪create_cassandra_initial_std_current_memory_2),
                   'peak': (create_cassandra_initial_mean_peak_memory_2,␣
 ↪create_cassandra_initial_std_peak_memory_2)},
        'READ': {'current': (read_cassandra_initial_mean_current_memory_2,␣
 ↪read_cassandra_initial_std_current_memory_2),
                 'peak': (read_cassandra_initial_mean_peak_memory_2,␣
 ↪read_cassandra_initial_std_peak_memory_2)},
        'UPDATE': {'current': (update_cassandra_initial_mean_current_memory_2,␣
 ↪update_cassandra_initial_std_current_memory_2),
                   'peak': (update_cassandra_initial_mean_peak_memory_2,␣
 ↪update_cassandra_initial_std_peak_memory_2)},
        'DELETE': {'current': (delete_cassandra_initial_mean_current_memory_2,␣
 ↪delete_cassandra_initial_std_current_memory_2),
                   'peak': (delete_cassandra_initial_mean_peak_memory_2,␣
 ↪delete_cassandra_initial_std_peak_memory_2)}
    },
```

```
    '5-replica': {
        'CREATE': {'current': (create_cassandra_initial_mean_current_memory_5,␣
 ↪create_cassandra_initial_std_current_memory_5),
                   'peak': (create_cassandra_initial_mean_peak_memory_5,␣
 ↪create_cassandra_initial_std_peak_memory_5)},
        'READ': {'current': (read_cassandra_initial_mean_current_memory_5,␣
 ↪read_cassandra_initial_std_current_memory_5),
                 'peak': (read_cassandra_initial_mean_peak_memory_5,␣
 ↪read_cassandra_initial_std_peak_memory_5)},
        'UPDATE': {'current': (update_cassandra_initial_mean_current_memory_5,␣
 ↪update_cassandra_initial_std_current_memory_5),
                   'peak': (update_cassandra_initial_mean_peak_memory_5,␣
 ↪update_cassandra_initial_std_peak_memory_5)},
        'DELETE': {'current': (delete_cassandra_initial_mean_current_memory_5,␣
 ↪delete_cassandra_initial_std_current_memory_5),
                   'peak': (delete_cassandra_initial_mean_peak_memory_5,␣
 ↪delete_cassandra_initial_std_peak_memory_5)}
    }
}

operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

# Préparation des données
sqlite_current_means = [sqlite_memory[op]['current'][0] for op in operations]
sqlite_current_stds = [sqlite_memory[op]['current'][1] for op in operations]
sqlite_peak_means = [sqlite_memory[op]['peak'][0] for op in operations]
sqlite_peak_stds = [sqlite_memory[op]['peak'][1] for op in operations]

cassandra_current_means = {replica:␣
 ↪[cassandra_memory[replica][op]['current'][0] for op in operations] for␣
 ↪replica in cassandra_memory}
cassandra_current_stds = {replica: [cassandra_memory[replica][op]['current'][1]␣
 ↪for op in operations] for replica in cassandra_memory}
cassandra_peak_means = {replica: [cassandra_memory[replica][op]['peak'][0] for␣
 ↪op in operations] for replica in cassandra_memory}
cassandra_peak_stds = {replica: [cassandra_memory[replica][op]['peak'][1] for␣
 ↪op in operations] for replica in cassandra_memory}

y = np.arange(len(operations))
height = 0.15

fig, ax = plt.subplots(2, 1, figsize=(14, 10))

colors = ['tab:red', 'tab:green', 'tab:orange']
# Current Memory
```

```
ax[0].barh(y + 2 * height, sqlite_current_means, height,␣
 ↪xerr=sqlite_current_stds, label='SQLite Current', color='tab:blue',␣
 ↪capsize=5)
for i, replica in enumerate(cassandra_memory):
    ax[0].barh(y + (1 - i) * height, cassandra_current_means[replica], height,␣
 ↪xerr=cassandra_current_stds[replica],
             label=f'Cassandra {replica} Current', capsize=5, color=colors[i])


colors = ['#FFCCCB', '#90EE90', '#FFD580']
# Peak Memory
ax[1].barh(y + 2 * height, sqlite_peak_means, height, xerr=sqlite_peak_stds,␣
 ↪label='SQLite Peak', color='#89CFF0', capsize=5)
for i, replica in enumerate(cassandra_memory):
    ax[1].barh(y + (1 - i) * height, cassandra_peak_means[replica], height,␣
 ↪xerr=cassandra_peak_stds[replica],
             label=f'Cassandra {replica} Peak', capsize=5, color=colors[i])

# Ajustements graphiques
for i in range(2):
    ax[i].set_xlabel('Mémoire utilisée (Mo)')
    ax[i].set_ylabel('Opérations CRUD')
    ax[i].set_yticks(y)
    ax[i].set_yticklabels(operations)
    ax[i].legend()
    ax[i].grid(axis='x', linestyle='--', alpha=0.7)

ax[0].set_title('Mémoire Current : SQLite vs Cassandra')
ax[1].set_title('Mémoire Peak : SQLite vs Cassandra')

plt.tight_layout()
plt.show()
```



Le constat est similaire à celui des tests précédents : SQLite se révèle nettement plus rapide que Cassandra dans la gestion des données, avec une performance de lecture plus rapide en Cassandra que les opérations de mise à jour et de suppression.

Sur les deux systèmes, l'opération de création (create) reste la plus longue, quel que soit le contexte.

Avec plusieurs replica sets, les différences de temps d'exécution sont négligeables. En tenant compte de l'erreur standard, les temps mesurés pour Cassandra avec 1, 2 et 5 réplicas sont pratiquement identiques. Il en va de même pour la consommation de mémoire, qui reste comparable quel que soit le nombre de réplicas.

3 Création d'un dataset plus grand

Dans le but de voir une réelle différence, nous allons utiliser une base de données plus grande.
En effet, Cassandra est mieux adapté pour gérer de grandes quantités de données et pour tirer parti de son architecture distribuée.
Nous allons donc augmenter la taille de notre jeu de données.

On crée nous même ce dataset car les sites de création de dataset ne permettent de télécharger que 1000 lignes avec un compte gratuit.

[30]:
```
df_initial.shape
```

[30]: (8807, 12)

[ ]:
```
original_df = df_initial

num_rows = 30000

def generate_large_column(original_column, size):
    return [random.choice(original_column) for _ in range(size)]

def generate_unique_show_id(existing_ids, size):
    start_id = max(existing_ids) + 1 if existing_ids else 1
    return [f"{i}" for i in range(start_id, start_id + size)]

generated_data = original_df.to_dict(orient='list')

existing_ids = set(map(int, original_df["show_id"].tolist()))
new_ids = generate_unique_show_id(existing_ids, num_rows - len(original_df))
generated_data["show_id"].extend(new_ids)

for column in original_df.columns:
    if column != "show_id":
        generated_data[column].extend(generate_large_column(original_df[column].
 ↪tolist(), num_rows - len(original_df)))

large_df = pd.DataFrame(generated_data)

large_df = large_df.drop_duplicates()

for column in large_df.columns:
    if large_df[column].isnull().any():
        if large_df[column].dtype == "object":
            large_df[column].fillna("Unknown", inplace=True)
        else:
            large_df[column].fillna(0, inplace=True)

large_df = large_df.drop_duplicates()

if large_df["show_id"].duplicated().any():
    print("Attention : Des doublons existent dans la colonne 'show_id'.")
else:
    print("Les IDs sont uniques.")

output_file = "data/netflix_titles_large.csv"
large_df.to_csv(output_file, index=False)
print(f"Dataset généré avec {len(large_df)} lignes (lignes dupliquées␣
 ↪supprimées) et exporté dans {output_file}.")
```

```
Les IDs sont uniques.
```

Dataset généré avec 30000 lignes (lignes dupliquées supprimées) et exporté dans netflix_titles_large.csv.

[32]:
```
large_df.shape
```

[32]:
```
(30000, 12)
```

[33]:
```
# Caster correctement les colonnes
large_df['show_id'] = large_df['show_id'].astype(int)

large_df['show_id'] = large_df['show_id'].astype(int)
large_df['release_year'] = large_df['release_year'].astype(int)

large_df['type'] = large_df['title'].astype(str)
large_df['title'] = large_df['title'].astype(str)
large_df['director'] = large_df['director'].astype(str)
large_df['cast'] = large_df['cast'].astype(str)
large_df['country'] = large_df['country'].astype(str)
large_df['date_added'] = large_df['date_added'].astype(str)
large_df['rating'] = large_df['rating'].astype(str)
large_df['duration'] = large_df['duration'].astype(str)
large_df['listed_in'] = large_df['listed_in'].astype(str)
large_df['description'] = large_df['description'].astype(str)
```

[34]:
```
# sqlite
# --- CREATE ---
create_sqlite_large_mean_time, create_sqlite_large_std_time, \
    create_sqlite_large_mean_current_memory,␣
 ↪create_sqlite_large_std_current_memory, \
        create_sqlite_large_mean_peak_memory,␣
 ↪create_sqlite_large_std_peak_memory = benchmark_operation(sqlite_insert,␣
 ↪large_df)

# --- READ ---
read_sqlite_large_mean_time, read_sqlite_large_std_time, \
    read_sqlite_large_mean_current_memory,␣
 ↪read_sqlite_large_std_current_memory, \
        read_sqlite_large_mean_peak_memory, read_sqlite_large_std_peak_memory =␣
 ↪benchmark_operation(sqlite_read, large_df)

# --- UPDATE ---
update_sqlite_large_mean_time, update_sqlite_large_std_time, \
    update_sqlite_large_mean_current_memory,␣
 ↪update_sqlite_large_std_current_memory, \
        update_sqlite_large_mean_peak_memory,␣
 ↪update_sqlite_large_std_peak_memory = benchmark_operation(sqlite_update,␣
 ↪large_df)
```

```
# --- DELETE ---
delete_sqlite_large_mean_time, delete_sqlite_large_std_time, \
    delete_sqlite_large_mean_current_memory,␣
 ↪delete_sqlite_large_std_current_memory, \
       delete_sqlite_large_mean_peak_memory,␣
 ↪delete_sqlite_large_std_peak_memory = benchmark_operation(sqlite_delete,␣
 ↪large_df)
```

```
Create Time: 1.305178 seconds
Current memory usage is 4.345832824707031Mo; Peak was 4.802192687988281Mo
Create Time: 1.256518 seconds
Current memory usage is 4.344351768493652Mo; Peak was 4.80078125Mo
Create Time: 1.325498 seconds
Current memory usage is 4.3442583084106445Mo; Peak was 4.80078125Mo
Create Time: 1.296202 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Create Time: 1.307091 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Create Time: 1.307871 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.003984 seconds
Queried 134 records
Current memory usage is 0.14043521881103516Mo; Peak was 0.14043521881103516Mo
Create Time: 1.311663 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.002791 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.307863 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.002754 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.301976 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.003605 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.293887 seconds
Current memory usage is 4.344037055969238Mo; Peak was 4.80078125Mo
Read Time: 0.002976 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.303817 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Update Time: 0.002195 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
```

```
0.0009527206420898438Mo
Create Time: 1.286900 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Update Time: 0.002340 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.345370 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Update Time: 0.002397 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.308412 seconds
Current memory usage is 4.343868255615234Mo; Peak was 4.80078125Mo
Update Time: 0.002191 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.311116 seconds
Current memory usage is 4.343573570251465Mo; Peak was 4.800727844238281Mo
Update Time: 0.003622 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.326627 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Delete Time: 0.002666 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.281314 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Delete Time: 0.002716 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.316186 seconds
Current memory usage is 4.3439836502075195Mo; Peak was 4.800727844238281Mo
Delete Time: 0.003041 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.308467 seconds
Current memory usage is 4.343573570251465Mo; Peak was 4.800727844238281Mo
Delete Time: 0.016565 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.306324 seconds
Current memory usage is 4.343573570251465Mo; Peak was 4.800727844238281Mo
Delete Time: 0.002922 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
```

[35]:
```
# Cassandra

# 1 replica
# --- CREATE ---
create_cassandra_large_mean_time, create_cassandra_large_std_time, \
    create_cassandra_large_mean_current_memory,␣
 ↪create_cassandra_large_std_current_memory, \
        create_cassandra_large_mean_peak_memory,␣
 ↪create_cassandra_large_std_peak_memory =␣
 ↪benchmark_operation(cassandra_insert, large_df, 1)

# --- READ ---
read_cassandra_large_mean_time, read_cassandra_large_std_time, \
    read_cassandra_large_mean_current_memory,␣
 ↪read_cassandra_large_std_current_memory, \
        read_cassandra_large_mean_peak_memory,␣
 ↪read_cassandra_large_std_peak_memory = benchmark_operation(cassandra_read,␣
 ↪large_df, 1)

# --- UPDATE ---
update_cassandra_large_mean_time, update_cassandra_large_std_time, \
    update_cassandra_large_mean_current_memory,␣
 ↪update_cassandra_large_std_current_memory, \
        update_cassandra_large_mean_peak_memory,␣
 ↪update_cassandra_large_std_peak_memory =␣
 ↪benchmark_operation(cassandra_update, large_df, 1)

# --- DELETE ---
delete_cassandra_large_mean_time, delete_cassandra_large_std_time, \
    delete_cassandra_large_mean_current_memory,␣
 ↪delete_cassandra_large_std_current_memory, \
        delete_cassandra_large_mean_peak_memory,␣
 ↪delete_cassandra_large_std_peak_memory =␣
 ↪benchmark_operation(cassandra_delete, large_df, 1)
```

```
replication factor = 1
Create Time: 14.107633 seconds
Current memory usage is 4.688434600830078Mo; Peak was 4.807888031005859Mo
replication factor = 1
Create Time: 13.920688 seconds
Current memory usage is 4.798870086669922Mo; Peak was 4.951694488525391Mo
replication factor = 1
Create Time: 13.814156 seconds
Current memory usage is 4.895030975341797Mo; Peak was 4.942122459411621Mo
replication factor = 1
Create Time: 13.891937 seconds
Current memory usage is 4.812722206115723Mo; Peak was 4.95905876159668Mo
```

```
replication factor = 1
Create Time: 14.025427 seconds
Current memory usage is 4.880401611328125Mo; Peak was 4.945127487182617Mo
replication factor = 1
Create Time: 14.464603 seconds
Current memory usage is 4.853646278381348Mo; Peak was 4.93635368347168Mo
Read Time: 0.028117 seconds
Queried 134 records
Current memory usage is 0.16408729553222656Mo; Peak was 0.3663520812988281Mo
replication factor = 1
Create Time: 14.028974 seconds
Current memory usage is 4.853952407836914Mo; Peak was 4.950373649597168Mo
Read Time: 0.027630 seconds
Queried 134 records
Current memory usage is 0.16376304626464844Mo; Peak was 0.366485595703125Mo
replication factor = 1
Create Time: 13.808341 seconds
Current memory usage is 4.831725120544434Mo; Peak was 4.949315071105957Mo
Read Time: 0.027643 seconds
Queried 134 records
Current memory usage is 0.1642284393310547Mo; Peak was 0.36632537841796875Mo
replication factor = 1
Create Time: 13.856862 seconds
Current memory usage is 4.846168518066406Mo; Peak was 4.942511558532715Mo
Read Time: 0.027342 seconds
Queried 134 records
Current memory usage is 0.16473960876464844Mo; Peak was 0.36568450927734375Mo
replication factor = 1
Create Time: 13.930895 seconds
Current memory usage is 4.860994338989258Mo; Peak was 4.961489677429199Mo
Read Time: 0.027327 seconds
Queried 134 records
Current memory usage is 0.16365623474121094Mo; Peak was 0.36632537841796875Mo
replication factor = 1
Create Time: 13.980761 seconds
Current memory usage is 4.817971229553223Mo; Peak was 4.941494941711426Mo
Update Time: 0.078613 seconds
Current memory usage is 0.088440850805664Mo; Peak was 0.17808818817138672Mo
replication factor = 1
Create Time: 13.793920 seconds
Current memory usage is 4.854570388793945Mo; Peak was 4.932570457458496Mo
Update Time: 0.078425 seconds
Current memory usage is 0.10232162475585938Mo; Peak was 0.16727924346923828Mo
replication factor = 1
Create Time: 13.977549 seconds
Current memory usage is 4.898832321166992Mo; Peak was 4.945525169372559Mo
Update Time: 0.078434 seconds
Current memory usage is 0.11895751953125Mo; Peak was 0.1682424545288086Mo
```

```
replication factor = 1
Create Time: 13.915493 seconds
Current memory usage is 4.757007598876953Mo; Peak was 4.93433952331543Mo
Update Time: 0.079216 seconds
Current memory usage is 0.13311195373535156Mo; Peak was 0.16834449768066406Mo
replication factor = 1
Create Time: 13.939312 seconds
Current memory usage is 4.619871139526367Mo; Peak was 4.821564674377441Mo
Update Time: 0.078943 seconds
Current memory usage is 0.10717582702636719Mo; Peak was 0.19434452056884766Mo
replication factor = 1
Create Time: 14.014219 seconds
Current memory usage is 4.884979248046875Mo; Peak was 4.939966201782227Mo
Delete Time: 0.078815 seconds
Current memory usage is 0.11185932159423828Mo; Peak was 0.16539859771728516Mo
replication factor = 1
Create Time: 13.920978 seconds
Current memory usage is 4.757612228393555Mo; Peak was 4.93560791015625Mo
Delete Time: 0.077908 seconds
Current memory usage is 0.13546371459960938Mo; Peak was 0.16948318481445312Mo
replication factor = 1
Create Time: 13.759200 seconds
Current memory usage is 4.783373832702637Mo; Peak was 4.933568000793457Mo
Delete Time: 0.077948 seconds
Current memory usage is 0.16417598724365234Mo; Peak was 0.1681356430053711Mo
replication factor = 1
Create Time: 14.008387 seconds
Current memory usage is 4.799084663391113Mo; Peak was 4.931363105773926Mo
Delete Time: 0.073790 seconds
Current memory usage is 0.07648277282714844Mo; Peak was 0.17461585998535156Mo
replication factor = 1
Create Time: 13.841961 seconds
Current memory usage is 4.817037582397461Mo; Peak was 4.931641578674316Mo
Delete Time: 0.078187 seconds
Current memory usage is 0.09132862091064453Mo; Peak was 0.17432022094726562Mo
```

[36]:
```
# 2 replicas
# --- CREATE ---
create_cassandra_large_mean_time_2, create_cassandra_large_std_time_2, \
    create_cassandra_large_mean_current_memory_2,␣
 ↪create_cassandra_large_std_current_memory_2, \
       create_cassandra_large_mean_peak_memory_2,␣
 ↪create_cassandra_large_std_peak_memory_2 =␣
 ↪benchmark_operation(cassandra_insert, large_df, 2)

# --- READ ---
read_cassandra_large_mean_time_2, read_cassandra_large_std_time_2, \
```

```
    read_cassandra_large_mean_current_memory_2,␣
 ↪read_cassandra_large_std_current_memory_2, \
        read_cassandra_large_mean_peak_memory_2,␣
 ↪read_cassandra_large_std_peak_memory_2 = benchmark_operation(cassandra_read,␣
 ↪large_df, 2)

# --- UPDATE ---
update_cassandra_large_mean_time_2, update_cassandra_large_std_time_2, \
    update_cassandra_large_mean_current_memory_2,␣
 ↪update_cassandra_large_std_current_memory_2, \
        update_cassandra_large_mean_peak_memory_2,␣
 ↪update_cassandra_large_std_peak_memory_2 =␣
 ↪benchmark_operation(cassandra_update, large_df, 2)

# --- DELETE ---
delete_cassandra_large_mean_time_2, delete_cassandra_large_std_time_2, \
    delete_cassandra_large_mean_current_memory_2,␣
 ↪delete_cassandra_large_std_current_memory_2, \
        delete_cassandra_large_mean_peak_memory_2,␣
 ↪delete_cassandra_large_std_peak_memory_2 =␣
 ↪benchmark_operation(cassandra_delete, large_df, 2)
```

```
replication factor = 2
Create Time: 13.967856 seconds
Current memory usage is 4.889211654663086Mo; Peak was 4.936692237854004Mo
replication factor = 2
Create Time: 13.829521 seconds
Current memory usage is 4.870688438415527Mo; Peak was 4.944897651672363Mo
replication factor = 2
Create Time: 13.867042 seconds
Current memory usage is 4.786284446716309Mo; Peak was 4.942944526672363Mo
replication factor = 2
Create Time: 13.858062 seconds
Current memory usage is 4.823310852050781Mo; Peak was 4.941587448120117Mo
replication factor = 2
Create Time: 13.874336 seconds
Current memory usage is 4.7931928634643555Mo; Peak was 4.942525863647461Mo
replication factor = 2
Create Time: 13.923305 seconds
Current memory usage is 4.825992584228516Mo; Peak was 4.9440155029296875Mo
Read Time: 0.027314 seconds
Queried 134 records
Current memory usage is 0.1651439666748047Mo; Peak was 0.36568450927734375Mo
replication factor = 2
Create Time: 13.891885 seconds
Current memory usage is 4.823423385620117Mo; Peak was 4.947366714477539Mo
Read Time: 0.023218 seconds
```

```
Queried 134 records
Current memory usage is 0.16365623474121094Mo; Peak was 0.36632537841796875Mo
replication factor = 2
Create Time: 13.963124 seconds
Current memory usage is 4.8469390869140625Mo; Peak was 4.947295188903809Mo
Read Time: 0.027683 seconds
Queried 134 records
Current memory usage is 0.1641674041748047Mo; Peak was 0.36589813232421875Mo
replication factor = 2
Create Time: 14.170877 seconds
Current memory usage is 4.661722183227539Mo; Peak was 4.818870544433594Mo
Read Time: 0.028141 seconds
Queried 134 records
Current memory usage is 0.1612834930419922Mo; Peak was 0.36797332763671875Mo
replication factor = 2
Create Time: 17.054005 seconds
Current memory usage is 4.8717041015625Mo; Peak was 4.94586181640625Mo
Read Time: 0.027353 seconds
Queried 134 records
Current memory usage is 0.15962791442871094Mo; Peak was 0.364990234375Mo
replication factor = 2
Create Time: 13.912388 seconds
Current memory usage is 4.902401924133301Mo; Peak was 4.943663597106934Mo
Update Time: 0.074195 seconds
Current memory usage is 0.10351181030273438Mo; Peak was 0.17036914825439453Mo
replication factor = 2
Create Time: 14.030951 seconds
Current memory usage is 4.912452697753906Mo; Peak was 4.927909851074219Mo
Update Time: 0.078548 seconds
Current memory usage is 0.11523246765136719Mo; Peak was 0.16544628143310547Mo
replication factor = 2
Create Time: 13.854558 seconds
Current memory usage is 4.798299789428711Mo; Peak was 4.935242652893066Mo
Update Time: 0.078859 seconds
Current memory usage is 0.14352703094482422Mo; Peak was 0.1652536392211914Mo
replication factor = 2
Create Time: 14.955814 seconds
Current memory usage is 4.831838607788086Mo; Peak was 4.932520866394043Mo
Update Time: 0.079028 seconds
Current memory usage is 0.07348918914794922Mo; Peak was 0.1659107208251953Mo
replication factor = 2
Create Time: 14.179144 seconds
Current memory usage is 4.875412940979004Mo; Peak was 4.930832862854004Mo
Update Time: 0.075975 seconds
Current memory usage is 0.10009193420410156Mo; Peak was 0.16454601287841797Mo
replication factor = 2
Create Time: 13.726897 seconds
Current memory usage is 4.911336898803711Mo; Peak was 4.930788040161133Mo
```

```
Delete Time: 0.078506 seconds
Current memory usage is 0.11500263214111328Mo; Peak was 0.16530609130859375Mo
replication factor = 2
Create Time: 14.002231 seconds
Current memory usage is 4.813784599304199Mo; Peak was 4.929076194763184Mo
Delete Time: 0.077985 seconds
Current memory usage is 0.06360530853271484Mo; Peak was 0.16930294036865234Mo
replication factor = 2
Create Time: 14.025068 seconds
Current memory usage is 4.843389511108398Mo; Peak was 4.930706977844238Mo
Delete Time: 0.078730 seconds
Current memory usage is 0.08068656921386719Mo; Peak was 0.16717243194580078Mo
replication factor = 2
Create Time: 13.871000 seconds
Current memory usage is 4.887635231018066Mo; Peak was 4.933239936828613Mo
Delete Time: 0.078517 seconds
Current memory usage is 0.1009378433227539Mo; Peak was 0.16533851623535156Mo
replication factor = 2
Create Time: 13.925801 seconds
Current memory usage is 4.916363716125488Mo; Peak was 4.932090759277344Mo
Delete Time: 0.078482 seconds
Current memory usage is 0.11441993713378906Mo; Peak was 0.1643228530883789Mo
```

[37]:
```
# 5 replicas
# --- CREATE ---
create_cassandra_large_mean_time_5, create_cassandra_large_std_time_5, \
    create_cassandra_large_mean_current_memory_5,␣
 ↪create_cassandra_large_std_current_memory_5, \
        create_cassandra_large_mean_peak_memory_5,␣
 ↪create_cassandra_large_std_peak_memory_5 =␣
 ↪benchmark_operation(cassandra_insert, large_df, 5)

# --- READ ---
read_cassandra_large_mean_time_5, read_cassandra_large_std_time_5, \
    read_cassandra_large_mean_current_memory_5,␣
 ↪read_cassandra_large_std_current_memory_5, \
        read_cassandra_large_mean_peak_memory_5,␣
 ↪read_cassandra_large_std_peak_memory_5 = benchmark_operation(cassandra_read,␣
 ↪large_df, 5)

# --- UPDATE ---
update_cassandra_large_mean_time_5, update_cassandra_large_std_time_5, \
    update_cassandra_large_mean_current_memory_5,␣
 ↪update_cassandra_large_std_current_memory_5, \
        update_cassandra_large_mean_peak_memory_5,␣
 ↪update_cassandra_large_std_peak_memory_5 =␣
 ↪benchmark_operation(cassandra_update, large_df, 5)
```

```
# --- DELETE ---
delete_cassandra_large_mean_time_5, delete_cassandra_large_std_time_5, \
    delete_cassandra_large_mean_current_memory_5,␣
 ↪delete_cassandra_large_std_current_memory_5, \
       delete_cassandra_large_mean_peak_memory_5,␣
 ↪delete_cassandra_large_std_peak_memory_5 =␣
 ↪benchmark_operation(cassandra_delete, large_df, 5)
```

```
replication factor = 5
Create Time: 14.223870 seconds
Current memory usage is 4.819451332092285Mo; Peak was 4.931177139282227Mo
replication factor = 5
Create Time: 13.727003 seconds
Current memory usage is 4.887795448303223Mo; Peak was 4.948267936706543Mo
replication factor = 5
Create Time: 13.931281 seconds
Current memory usage is 4.870937347412109Mo; Peak was 4.973318099975586Mo
replication factor = 5
Create Time: 13.916015 seconds
Current memory usage is 4.891016006469727Mo; Peak was 4.960564613342285Mo
replication factor = 5
Create Time: 13.787439 seconds
Current memory usage is 4.806285858154297Mo; Peak was 4.951393127441406Mo
replication factor = 5
Create Time: 13.793573 seconds
Current memory usage is 4.847027778625488Mo; Peak was 4.94300651550293Mo
Read Time: 0.027990 seconds
Queried 134 records
Current memory usage is 0.1593532562255859 4Mo; Peak was 0.36685943603515625Mo
replication factor = 5
Create Time: 13.961192 seconds
Current memory usage is 4.889833450317383Mo; Peak was 4.944729804992676Mo
Read Time: 0.025649 seconds
Queried 134 records
Current memory usage is 0.15952110290527344Mo; Peak was 0.36685943603515625Mo
replication factor = 5
Create Time: 13.883060 seconds
Current memory usage is 4.893740653991699Mo; Peak was 4.94929313659668Mo
Read Time: 0.028128 seconds
Queried 134 records
Current memory usage is 0.1590557098388672Mo; Peak was 0.364990234375Mo
replication factor = 5
Create Time: 13.770196 seconds
Current memory usage is 4.859872817993164Mo; Peak was 4.951977729797363Mo
Read Time: 0.028152 seconds
Queried 134 records
Current memory usage is 0.15952110290527344Mo; Peak was 0.36685943603515625Mo
```

```
replication factor = 5
Create Time: 13.847259 seconds
Current memory usage is 4.864027976989746Mo; Peak was 4.942117691040039Mo
Read Time: 0.027848 seconds
Queried 134 records
Current memory usage is 0.1643352508544922Mo; Peak was 0.366485595703125Mo
replication factor = 5
Create Time: 13.820907 seconds
Current memory usage is 4.8344573974609375Mo; Peak was 4.943371772766113Mo
Update Time: 0.078489 seconds
Current memory usage is 0.09422492980957031Mo; Peak was 0.1784963607788086Mo
replication factor = 5
Create Time: 13.795892 seconds
Current memory usage is 4.865212440490723Mo; Peak was 4.937065124511719Mo
Update Time: 0.077989 seconds
Current memory usage is 0.10251617431640625Mo; Peak was 0.16773700714111328Mo
replication factor = 5
Create Time: 13.914717 seconds
Current memory usage is 4.904356956481934Mo; Peak was 4.941092491149902Mo
Update Time: 0.077542 seconds
Current memory usage is 0.11761474609375Mo; Peak was 0.1683340072631836Mo
replication factor = 5
Create Time: 13.879489 seconds
Current memory usage is 4.782889366149902Mo; Peak was 4.937871932983398Mo
Update Time: 0.077611 seconds
Current memory usage is 0.1505451202392578Mo; Peak was 0.16868305206298828Mo
replication factor = 5
Create Time: 13.860620 seconds
Current memory usage is 4.8020172119140625Mo; Peak was 4.932265281677246Mo
Update Time: 0.077639 seconds
Current memory usage is 0.07169342041015625Mo; Peak was 0.17581558227539062Mo
replication factor = 5
Create Time: 13.824617 seconds
Current memory usage is 4.857146263122559Mo; Peak was 4.9354143142700195Mo
Delete Time: 0.077291 seconds
Current memory usage is 0.10471153259277344Mo; Peak was 0.1698141098022461Mo
replication factor = 5
Create Time: 14.053926 seconds
Current memory usage is 4.783779144287109Mo; Peak was 4.928886413574219Mo
Delete Time: 0.078298 seconds
Current memory usage is 0.1838521957397461Mo; Peak was 0.187591552734375Mo
replication factor = 5
Create Time: 13.955975 seconds
Current memory usage is 4.856250762939453Mo; Peak was 4.938878059387207Mo
Delete Time: 0.078214 seconds
Current memory usage is 0.10471153259277344Mo; Peak was 0.16896724700927734Mo
replication factor = 5
Create Time: 13.805594 seconds
```

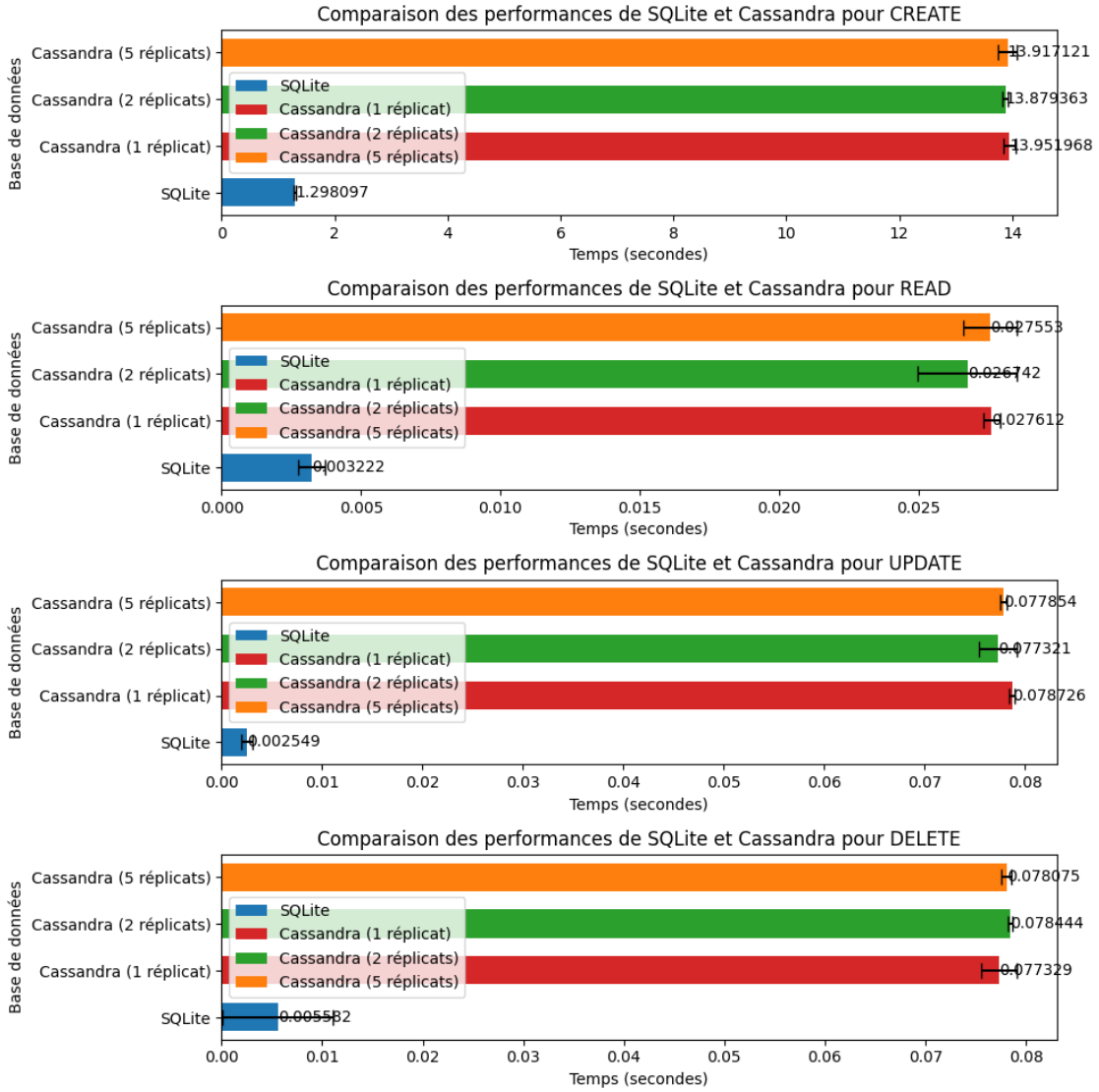
```
Current memory usage is 4.897345542907715Mo; Peak was 4.935214996337891Mo
Delete Time: 0.078759 seconds
Current memory usage is 0.11410903930664062Mo; Peak was 0.1684579849243164Mo
replication factor = 5
Create Time: 13.815739 seconds
Current memory usage is 4.768063545227051Mo; Peak was 4.933548927307129Mo
Delete Time: 0.077813 seconds
Current memory usage is 0.13636493682861328Mo; Peak was 0.17143726348876953Mo
```

3.1 Visualisation

[38]:
```
sqlite_times = {
    'CREATE': (create_sqlite_large_mean_time, create_sqlite_large_std_time),
    'READ': (read_sqlite_large_mean_time, read_sqlite_large_std_time),
    'UPDATE': (update_sqlite_large_mean_time, update_sqlite_large_std_time),
    'DELETE': (delete_sqlite_large_mean_time, delete_sqlite_large_std_time)
}

cassandra_times = {
    'CREATE': (create_cassandra_large_mean_time,␣
 ↪create_cassandra_large_std_time),
    'READ': (read_cassandra_large_mean_time, read_cassandra_large_std_time),
    'UPDATE': (update_cassandra_large_mean_time,␣
 ↪update_cassandra_large_std_time),
    'DELETE': (delete_cassandra_large_mean_time,␣
 ↪delete_cassandra_large_std_time)
}

cassandra_times_2 = {
    'CREATE': (create_cassandra_large_mean_time_2,␣
 ↪create_cassandra_large_std_time_2),
    'READ': (read_cassandra_large_mean_time_2, read_cassandra_large_std_time_2),
    'UPDATE': (update_cassandra_large_mean_time_2,␣
 ↪update_cassandra_large_std_time_2),
    'DELETE': (delete_cassandra_large_mean_time_2,␣
 ↪delete_cassandra_large_std_time_2)
}

cassandra_times_5 = {
    'CREATE': (create_cassandra_large_mean_time_5,␣
 ↪create_cassandra_large_std_time_5),
    'READ': (read_cassandra_large_mean_time_5, read_cassandra_large_std_time_5),
    'UPDATE': (update_cassandra_large_mean_time_5,␣
 ↪update_cassandra_large_std_time_5),
    'DELETE': (delete_cassandra_large_mean_time_5,␣
 ↪delete_cassandra_large_std_time_5)
}
```

```
operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

# Extraire les temps moyens et écarts-types pour chaque système
sqlite_means = [sqlite_times[op][0] for op in operations]
sqlite_stds = [sqlite_times[op][1] for op in operations]

cassandra_means = [cassandra_times[op][0] for op in operations]
cassandra_stds = [cassandra_times[op][1] for op in operations]

cassandra_means_2 = [cassandra_times_2[op][0] for op in operations]
cassandra_stds_2 = [cassandra_times_2[op][1] for op in operations]

cassandra_means_5 = [cassandra_times_5[op][0] for op in operations]
cassandra_stds_5 = [cassandra_times_5[op][1] for op in operations]

# Créer un graphique pour chaque opération
fig, axes = plt.subplots(4, 1, figsize=(10, 10))  # 4 graphiques sous le même␣
 ↪format
height = 0.6

# Générer chaque sous-graphe pour chaque opération
for i, op in enumerate(operations):
    ax = axes[i]
    y = np.arange(4)  # Quatre barres par graphique : SQLite, Cassandra (1),␣
 ↪(2) et (5) réplicats

    # Dessiner les barres pour SQLite et Cassandra avec différents réplicats
    bars1 = ax.barh(y[0] , sqlite_times[op][0], height,␣
 ↪xerr=sqlite_times[op][1], label='SQLite', capsize=5, color='tab:blue')
    bars2 = ax.barh(y[1] , cassandra_times[op][0], height,␣
 ↪xerr=cassandra_times[op][1], label='Cassandra (1 réplicat)', capsize=5,␣
 ↪color='tab:red')
    bars3 = ax.barh(y[2], cassandra_times_2[op][0], height,␣
 ↪xerr=cassandra_times_2[op][1], label='Cassandra (2 réplicats)', capsize=5,␣
 ↪color='tab:green')
    bars4 = ax.barh(y[3], cassandra_times_5[op][0], height,␣
 ↪xerr=cassandra_times_5[op][1], label='Cassandra (5 réplicats)', capsize=5,␣
 ↪color='tab:orange')

    # Titre et labels
    ax.set_xlabel('Temps (secondes)')
    ax.set_ylabel('Base de données')
    ax.set_title(f'Comparaison des performances de SQLite et Cassandra pour␣
 ↪{op}')
    ax.set_yticks(y)
```

```
    ax.set_yticklabels(['SQLite', 'Cassandra (1 réplicat)', 'Cassandra (2␣
↪réplicats)', 'Cassandra (5 réplicats)'])
    ax.legend()

    # Ajouter les valeurs aux barres
    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
↪va='center', ha='left')

    add_values(bars1)
    add_values(bars2)
    add_values(bars3)
    add_values(bars4)

# Ajuster l'espacement entre les graphiques
plt.tight_layout()
plt.show()
```

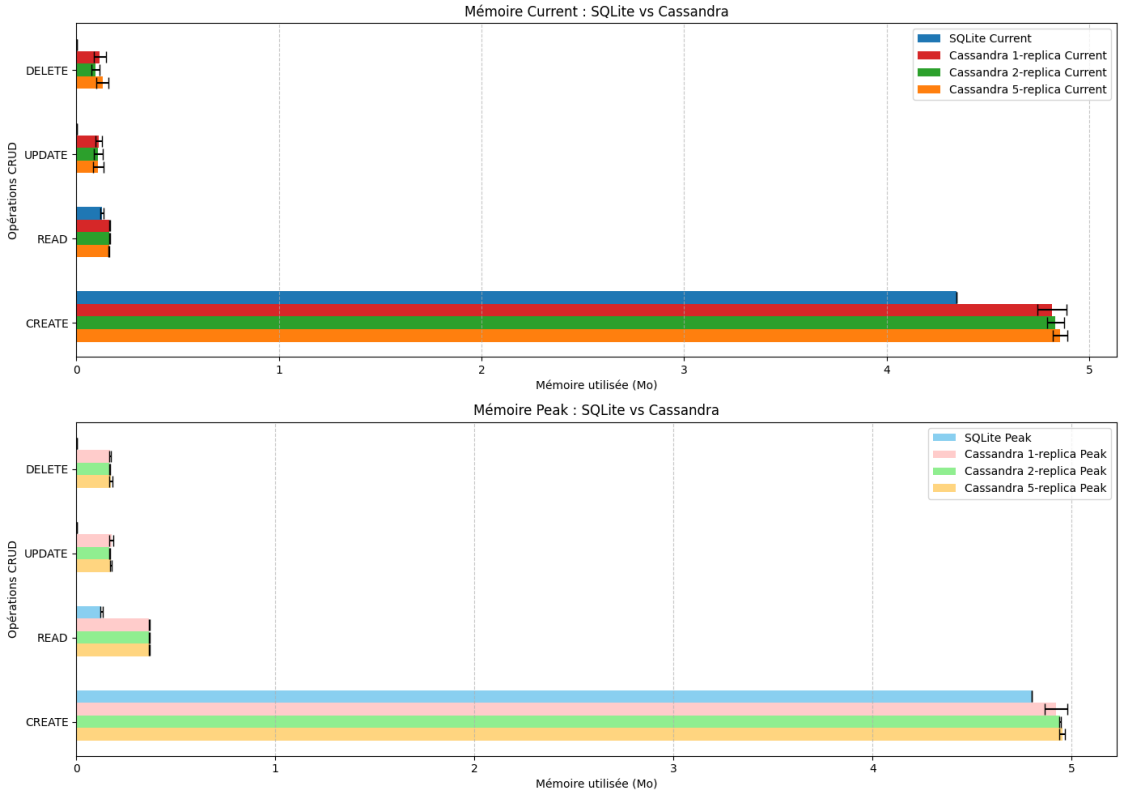


[39]:
```
# Valeurs de mémoire pour SQLite
sqlite_memory = {
    'CREATE': {'current': (create_sqlite_large_mean_current_memory,␣
 ↪create_sqlite_large_std_current_memory),
               'peak': (create_sqlite_large_mean_peak_memory,␣
 ↪create_sqlite_large_std_peak_memory)},
    'READ': {'current': (read_sqlite_large_mean_current_memory,␣
 ↪read_sqlite_large_std_current_memory),
             'peak': (read_sqlite_large_mean_peak_memory,␣
 ↪read_sqlite_large_std_peak_memory)},
    'UPDATE': {'current': (update_sqlite_large_mean_current_memory,␣
 ↪update_sqlite_large_std_current_memory),
```

```
                'peak': (update_sqlite_large_mean_peak_memory,␣
 ↪update_sqlite_large_std_peak_memory)},
    'DELETE': {'current': (delete_sqlite_large_mean_current_memory,␣
 ↪delete_sqlite_large_std_current_memory),
                'peak': (delete_sqlite_large_mean_peak_memory,␣
 ↪delete_sqlite_large_std_peak_memory)}
}

# Valeurs de mémoire pour Cassandra avec différentes réplications
cassandra_memory = {
    '1-replica': {
        'CREATE': {'current': (create_cassandra_large_mean_current_memory,␣
 ↪create_cassandra_large_std_current_memory),
                   'peak': (create_cassandra_large_mean_peak_memory,␣
 ↪create_cassandra_large_std_peak_memory)},
        'READ': {'current': (read_cassandra_large_mean_current_memory,␣
 ↪read_cassandra_large_std_current_memory),
                 'peak': (read_cassandra_large_mean_peak_memory,␣
 ↪read_cassandra_large_std_peak_memory)},
        'UPDATE': {'current': (update_cassandra_large_mean_current_memory,␣
 ↪update_cassandra_large_std_current_memory),
                   'peak': (update_cassandra_large_mean_peak_memory,␣
 ↪update_cassandra_large_std_peak_memory)},
        'DELETE': {'current': (delete_cassandra_large_mean_current_memory,␣
 ↪delete_cassandra_large_std_current_memory),
                   'peak': (delete_cassandra_large_mean_peak_memory,␣
 ↪delete_cassandra_large_std_peak_memory)}
    },
    '2-replica': {
        'CREATE': {'current': (create_cassandra_large_mean_current_memory_2,␣
 ↪create_cassandra_large_std_current_memory_2),
                   'peak': (create_cassandra_large_mean_peak_memory_2,␣
 ↪create_cassandra_large_std_peak_memory_2)},
        'READ': {'current': (read_cassandra_large_mean_current_memory_2,␣
 ↪read_cassandra_large_std_current_memory_2),
                 'peak': (read_cassandra_large_mean_peak_memory_2,␣
 ↪read_cassandra_large_std_peak_memory_2)},
        'UPDATE': {'current': (update_cassandra_large_mean_current_memory_2,␣
 ↪update_cassandra_large_std_current_memory_2),
                   'peak': (update_cassandra_large_mean_peak_memory_2,␣
 ↪update_cassandra_large_std_peak_memory_2)},
        'DELETE': {'current': (delete_cassandra_large_mean_current_memory_2,␣
 ↪delete_cassandra_large_std_current_memory_2),
                   'peak': (delete_cassandra_large_mean_peak_memory_2,␣
 ↪delete_cassandra_large_std_peak_memory_2)}
    },
```

```
    '5-replica': {
        'CREATE': {'current': (create_cassandra_large_mean_current_memory_5,␣
 ↪create_cassandra_large_std_current_memory_5),
                   'peak': (create_cassandra_large_mean_peak_memory_5,␣
 ↪create_cassandra_large_std_peak_memory_5)},
        'READ': {'current': (read_cassandra_large_mean_current_memory_5,␣
 ↪read_cassandra_large_std_current_memory_5),
                 'peak': (read_cassandra_large_mean_peak_memory_5,␣
 ↪read_cassandra_large_std_peak_memory_5)},
        'UPDATE': {'current': (update_cassandra_large_mean_current_memory_5,␣
 ↪update_cassandra_large_std_current_memory_5),
                   'peak': (update_cassandra_large_mean_peak_memory_5,␣
 ↪update_cassandra_large_std_peak_memory_5)},
        'DELETE': {'current': (delete_cassandra_large_mean_current_memory_5,␣
 ↪delete_cassandra_large_std_current_memory_5),
                   'peak': (delete_cassandra_large_mean_peak_memory_5,␣
 ↪delete_cassandra_large_std_peak_memory_5)}
    }
}

operations = ['CREATE', 'READ', 'UPDATE', 'DELETE']

# Préparation des données
sqlite_current_means = [sqlite_memory[op]['current'][0] for op in operations]
sqlite_current_stds = [sqlite_memory[op]['current'][1] for op in operations]
sqlite_peak_means = [sqlite_memory[op]['peak'][0] for op in operations]
sqlite_peak_stds = [sqlite_memory[op]['peak'][1] for op in operations]

cassandra_current_means = {replica:␣
 ↪[cassandra_memory[replica][op]['current'][0] for op in operations] for␣
 ↪replica in cassandra_memory}
cassandra_current_stds = {replica: [cassandra_memory[replica][op]['current'][1]␣
 ↪for op in operations] for replica in cassandra_memory}
cassandra_peak_means = {replica: [cassandra_memory[replica][op]['peak'][0] for␣
 ↪op in operations] for replica in cassandra_memory}
cassandra_peak_stds = {replica: [cassandra_memory[replica][op]['peak'][1] for␣
 ↪op in operations] for replica in cassandra_memory}

y = np.arange(len(operations))
height = 0.15

fig, ax = plt.subplots(2, 1, figsize=(14, 10))

colors = ['tab:red', 'tab:green', 'tab:orange']
# Current Memory
```

```
ax[0].barh(y + 2 * height, sqlite_current_means, height,␣
 ↪xerr=sqlite_current_stds, label='SQLite Current', color='tab:blue',␣
 ↪capsize=5)
for i, replica in enumerate(cassandra_memory):
    ax[0].barh(y + (1 - i) * height, cassandra_current_means[replica], height,␣
 ↪xerr=cassandra_current_stds[replica],
             label=f'Cassandra {replica} Current', capsize=5, color=colors[i])


colors = ['#FFCCCB', '#90EE90', '#FFD580']
# Peak Memory
ax[1].barh(y + 2 * height, sqlite_peak_means, height, xerr=sqlite_peak_stds,␣
 ↪label='SQLite Peak', color='#89CFF0', capsize=5)
for i, replica in enumerate(cassandra_memory):
    ax[1].barh(y + (1 - i) * height, cassandra_peak_means[replica], height,␣
 ↪xerr=cassandra_peak_stds[replica],
             label=f'Cassandra {replica} Peak', capsize=5, color=colors[i])

# Ajustements graphiques
for i in range(2):
    ax[i].set_xlabel('Mémoire utilisée (Mo)')
    ax[i].set_ylabel('Opérations CRUD')
    ax[i].set_yticks(y)
    ax[i].set_yticklabels(operations)
    ax[i].legend()
    ax[i].grid(axis='x', linestyle='--', alpha=0.7)

ax[0].set_title('Mémoire Current : SQLite vs Cassandra')
ax[1].set_title('Mémoire Peak : SQLite vs Cassandra')

plt.tight_layout()
plt.show()
```



Sur un dataset plus large, les résultats ne permettent pas de tirer des conclusions claires: - les temps sont tous à peu près identiques entre 1, 2 et 5 replica sets pour une opération donnée. - Côté mémoire, aucune variation notable n'a été observée entre les configurations.

Globalement, l'augmentation de la taille des données, de 8k à 30k, n'apporte pas d'insights significatifs.

4 Comparaison avec / sans index

4.0.1 Index secondaires (clés secondaires)

Dans Cassandra, la commande `CREATE INDEX` permet de créer des index secondaires, qui ne sont pas des clés primaires. Cela permet de filtrer les données sur des colonnes autres que la partition key ou les clustering keys.

Avantages des index secondaires

- Facilite les filtres sur des colonnes non clés : Vous pouvez filtrer sur des colonnes autres que la partition key ou les clustering keys, ce qui rend les requêtes plus flexibles.
- Accès plus rapide aux données : Les index secondaires optimisent les requêtes qui filtrent sur certaines colonnes spécifiques, réduisant le nombre de partitions à examiner.

Inconvénients des index secondaires

- Risque de surcharge de performance : Sur de grandes tables, si une colonne contient beaucoup de valeurs distinctes, l'index peut devenir lourd et ralentir les performances des écritures et lectures.
- Structure distribuée moins efficace : Les index secondaires sont distribués, mais leur gestion est moins performante que les clés primaires, surtout sur des colonnes avec une haute cardinalité.
- Limitations d'usage : Les index secondaires sont mieux utilisés sur des colonnes avec faible cardinalité. Il est déconseillé de les utiliser pour des colonnes ayant une forte cardinalité ou pour des filtres complexes impliquant plusieurs colonnes.
- `ALLOW FILTERING` : Parfois, pour exécuter une requête avec un index secondaire (utilisation de `<` ou `>` par exemple), il est obligatoire d'utiliser `ALLOW FILTERING`, ce qui peut nuire aux performances en scannant une grande partie des données.

[40]:
```python
def cassandra_create_indexes(columns):
    tracemalloc.start()
    start_time = time.time()
    for column in columns:
        index_query = f"CREATE INDEX {column}_idx ON shows ({column});"
        session.execute(index_query)
    cassandra_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    return cassandra_time, current, peak


def sqlite_create_indexes(columns):
    # drop les index
    for column in columns:
        index_query = f"DROP INDEX IF EXISTS {column}_idx;"
        cursor.execute(index_query)

    tracemalloc.start()
    start_time = time.time()
    for column in columns:
        # Créer une requête SQL pour chaque colonne
        index_query = f"CREATE INDEX IF NOT EXISTS {column}_idx ON shows␣
 ↪({column});"
        cursor.execute(index_query)
    sqlite_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    return sqlite_time, current, peak
```

```
columns_to_index = ["release_year"]
cassandra_time_index, cassandra_current_index, cassandra_peak_index =␣
 ↪cassandra_create_indexes(columns_to_index)
sqlite_time_index, sqlite_current_index, sqlite_peak_index =␣
 ↪sqlite_create_indexes(columns_to_index)

print(f"Indexation time: Cassandra {cassandra_time_index:.5f}s, SQLite␣
 ↪{sqlite_time_index:.5f}s")
print(f"Current memory: Cassandra {cassandra_current_index:.5f}Mo, SQLite␣
 ↪{sqlite_current_index:.5f}Mo")
```

```
Indexation time: Cassandra 0.17675s, SQLite 0.00783s
Current memory: Cassandra 0.04068Mo, SQLite 0.00044Mo
```

[41]:
```
# Fonctions pour CRUD SQLite avec index

# --- CREATE ---
def sqlite_insert_index(df):
    drop_table_sqlite()
    create_table_sqlite()
    sqlite_create_indexes(columns_to_index)

    columns = ', '.join(df.columns)
    placeholders = ', '.join(['?'] * len(df.columns))
    insert_query = f"INSERT INTO shows ({columns}) VALUES ({placeholders})"

    tracemalloc.start()
    start_time = time.time()
    for _, row in df.iterrows():
      cursor.execute(insert_query, tuple(row))
    conn.commit()

    create_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Create Time: {create_time_sqlite:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return create_time_sqlite, current, peak

# --- READ ---
def sqlite_read_index(df):
    sqlite_insert_index(df)
    tracemalloc.start()
    start_time = time.time()
    cursor.execute("SELECT * FROM shows WHERE release_year = 2000")
```

```
    result = cursor.fetchall()
    read_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Read Time: {read_time_sqlite:.6f} seconds")
    print(f"Queried {len(result)} records")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return read_time_sqlite, current, peak

# --- UPDATE ---
def sqlite_update_index(df):
    sqlite_insert_index(df)
    tracemalloc.start()
    start_time = time.time()
    cursor.execute("UPDATE shows SET rating='PG' WHERE release_year = 2000")
    conn.commit()
    update_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Update Time: {update_time_sqlite:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return update_time_sqlite, current, peak

# --- DELETE ---
def sqlite_delete_index(df):
    sqlite_insert_index(df)
    tracemalloc.start()
    start_time = time.time()
    cursor.execute("DELETE FROM shows WHERE release_year = 2000")
    conn.commit()
    delete_time_sqlite = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Delete Time: {delete_time_sqlite:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return delete_time_sqlite, current, peak
```

[42]:
```
# Fonctions pour CRUD Cassandra avec index

# --- CREATE ---
def cassandra_insert_index(*args):
```

```
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques

    drop_table_cassandra()
    create_table_cassandra(nb_repl)
    cassandra_create_indexes(columns_to_index)

    insert_query = session.prepare("INSERT INTO shows (show_id, title,␣
 ↪director, cast, country, date_added, release_year, rating, duration,␣
 ↪listed_in, description) VALUES (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)")

    tracemalloc.start()
    start_time = time.time()
    for _, row in df.iterrows():
        session.execute(insert_query, (row['show_id'], row['title'],␣
 ↪row['director'], row['cast'], row['country'], row['date_added'],␣
 ↪row['release_year'], row['rating'], row['duration'], row['listed_in'],␣
 ↪row['description']))
    create_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()

    print(f"Create Time: {create_time:.6f} seconds")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")

    return create_time, current, peak


# --- READ ---
def cassandra_read_index(*args):
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques
    cassandra_insert_index(df, nb_repl)

    tracemalloc.start()
    start_time = time.time()
    result = session.execute('SELECT * FROM shows WHERE release_year = 2000 ;')␣
 ↪# ici pas de allow filtering !
    read_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Read time with index: {read_time:.5f}s")
    num_records = sum(1 for _ in result)
```

```
    print(f"Number of records: {num_records}")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return read_time, current, peak

# Dans Cassandra, pour effectuer un UPDATE, il est nécessaire de spécifier la␣
 ↪clé primaire complète (partition key + clustering key).
# Par conséquent, il n'est pas possible de mettre à jour des lignes en fonction␣
 ↪de critères de recherche arbitraires, sauf si ces critères correspondent␣
 ↪exactement à la clé primaire.

# --- UPDATE ---
def cassandra_update_index(*args):
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques
    cassandra_insert_index(df, nb_repl)

    tracemalloc.start()
    start_time = time.time()
    select_query = "SELECT show_id FROM shows WHERE release_year = 2000;"
    result = session.execute(select_query)
    show_ids_to_update = [row.show_id for row in result]
    for show_id in show_ids_to_update:
        update_query = f"UPDATE shows SET rating = 'PG' WHERE show_id =␣
 ↪{show_id};"
        session.execute(update_query)
    update_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Update time with index: {update_time:.5f}s")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return update_time, current, peak


# --- DELETE ---
def cassandra_delete_index(*args):
    df = args[0]  # Premier argument, qui est le DataFrame
    nb_repl = args[1]  # Deuxième argument, qui est le nombre de répliques
    cassandra_insert_index(df, nb_repl)

    tracemalloc.start()
    start_time = time.time()
    select_query = "SELECT show_id FROM shows WHERE release_year = 2000;"
    result = session.execute(select_query)
    show_ids_to_delete = [row.show_id for row in result]
    for show_id in show_ids_to_delete:
```

```
        delete_query = f"DELETE FROM shows WHERE show_id = {show_id};"
        session.execute(delete_query)
    delete_time = time.time() - start_time
    current, peak = tracemalloc.get_traced_memory()
    current = current / 1024 / 1024
    peak = peak / 1024 / 1024
    tracemalloc.stop()
    print(f"Delete time with index: {delete_time:.5f}s")
    print(f"Current memory usage is {current}Mo; Peak was {peak}Mo")
    return delete_time, current, peak
```

[43]:
```
# sqlite
# --- CREATE ---
create_sqlite_large_mean_time_index, create_sqlite_large_std_time_index, \
    create_sqlite_large_mean_current_memory_index,␣
 ↪create_sqlite_large_std_current_memory_index, \
        create_sqlite_large_mean_peak_memory_index,␣
 ↪create_sqlite_large_std_peak_memory_index =␣
 ↪benchmark_operation(sqlite_insert_index, large_df)

# --- READ ---
read_sqlite_large_mean_time_index, read_sqlite_large_std_time_index, \
    read_sqlite_large_mean_current_memory_index,␣
 ↪read_sqlite_large_std_current_memory_index, \
        read_sqlite_large_mean_peak_memory_index,␣
 ↪read_sqlite_large_std_peak_memory_index =␣
 ↪benchmark_operation(sqlite_read_index, large_df)

# --- UPDATE ---
update_sqlite_large_mean_time_index, update_sqlite_large_std_time_index, \
    update_sqlite_large_mean_current_memory_index,␣
 ↪update_sqlite_large_std_current_memory_index, \
        update_sqlite_large_mean_peak_memory_index,␣
 ↪update_sqlite_large_std_peak_memory_index =␣
 ↪benchmark_operation(sqlite_update_index, large_df)

# --- DELETE ---
delete_sqlite_large_mean_time_index, delete_sqlite_large_std_time_index, \
    delete_sqlite_large_mean_current_memory_index,␣
 ↪delete_sqlite_large_std_current_memory_index, \
        delete_sqlite_large_mean_peak_memory_index,␣
 ↪delete_sqlite_large_std_peak_memory_index =␣
 ↪benchmark_operation(sqlite_delete_index, large_df)
```

```
Create Time: 1.349567 seconds
Current memory usage is 4.377193450927734Mo; Peak was 4.80078125Mo
Create Time: 1.325668 seconds
```

```
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Create Time: 1.349469 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Create Time: 1.317671 seconds
Current memory usage is 4.344037055969238Mo; Peak was 4.80078125Mo
Create Time: 1.351858 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Create Time: 1.350467 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.000808 seconds
Queried 134 records
Current memory usage is 0.1402902603149414Mo; Peak was 0.1402902603149414Mo
Create Time: 1.335281 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.000773 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.332309 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.000779 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.327412 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.000766 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.337816 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Read Time: 0.000760 seconds
Queried 134 records
Current memory usage is 0.12239933013916016Mo; Peak was 0.12239933013916016Mo
Create Time: 1.312834 seconds
Current memory usage is 4.344037055969238Mo; Peak was 4.80078125Mo
Update Time: 0.000268 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.344462 seconds
Current memory usage is 4.34384822845459Mo; Peak was 4.80078125Mo
Update Time: 0.000272 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.313452 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Update Time: 0.000237 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.330820 seconds
```

```
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Update Time: 0.000235 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.337018 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Update Time: 0.000520 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.337966 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Delete Time: 0.000457 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.312908 seconds
Current memory usage is 4.343626976013184Mo; Peak was 4.80078125Mo
Delete Time: 0.000274 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.344080 seconds
Current memory usage is 4.343573570251465Mo; Peak was 4.800727844238281Mo
Delete Time: 0.000291 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.327627 seconds
Current memory usage is 4.3439836502075195Mo; Peak was 4.800727844238281Mo
Delete Time: 0.000301 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
Create Time: 1.342303 seconds
Current memory usage is 4.343573570251465Mo; Peak was 4.800727844238281Mo
Delete Time: 0.000300 seconds
Current memory usage is 0.00047588348388671875Mo; Peak was
0.0009527206420898438Mo
```

[44]:
```
# Cassandra

# 1 replica
# --- CREATE ---
create_cassandra_large_mean_time_index, create_cassandra_large_std_time_index, \
    create_cassandra_large_mean_current_memory_index,␣
 ↪create_cassandra_large_std_current_memory_index, \
       create_cassandra_large_mean_peak_memory_index,␣
 ↪create_cassandra_large_std_peak_memory_index =␣
 ↪benchmark_operation(cassandra_insert_index, large_df, 1)

# --- READ ---
```

```
read_cassandra_large_mean_time_index, read_cassandra_large_std_time_index, \
    read_cassandra_large_mean_current_memory_index,␣
 ↪read_cassandra_large_std_current_memory_index, \
        read_cassandra_large_mean_peak_memory_index,␣
 ↪read_cassandra_large_std_peak_memory_index =␣
 ↪benchmark_operation(cassandra_read_index, large_df, 1)

# --- UPDATE ---
update_cassandra_large_mean_time_index, update_cassandra_large_std_time_index, \
    update_cassandra_large_mean_current_memory_index,␣
 ↪update_cassandra_large_std_current_memory_index, \
        update_cassandra_large_mean_peak_memory_index,␣
 ↪update_cassandra_large_std_peak_memory_index =␣
 ↪benchmark_operation(cassandra_update_index, large_df, 1)

# --- DELETE ---
delete_cassandra_large_mean_time_index, delete_cassandra_large_std_time_index, \
    delete_cassandra_large_mean_current_memory_index,␣
 ↪delete_cassandra_large_std_current_memory_index, \
        delete_cassandra_large_mean_peak_memory_index,␣
 ↪delete_cassandra_large_std_peak_memory_index =␣
 ↪benchmark_operation(cassandra_delete_index, large_df, 1)
```

```
replication factor = 1
Create Time: 14.049651 seconds
Current memory usage is 4.759546279907227Mo; Peak was 4.949460983276367Mo
replication factor = 1
Create Time: 13.730568 seconds
Current memory usage is 4.829494476318359Mo; Peak was 4.956901550292969Mo
replication factor = 1
Create Time: 13.843877 seconds
Current memory usage is 4.7814435958862305Mo; Peak was 4.950384140014648Mo
replication factor = 1
Create Time: 13.890019 seconds
Current memory usage is 4.911746025085449Mo; Peak was 4.962780952453613Mo
replication factor = 1
Create Time: 13.936144 seconds
Current memory usage is 4.928504943847656Mo; Peak was 4.961515426635742Mo
replication factor = 1
Create Time: 13.888104 seconds
Current memory usage is 4.878230094909668Mo; Peak was 4.9413957595825195Mo
Read time with index: 0.00571s
Number of records: 134
Current memory usage is 0.15943336486816406Mo; Peak was 0.3668327331542969Mo
replication factor = 1
Create Time: 13.900511 seconds
Current memory usage is 4.891768455505371Mo; Peak was 4.952357292175293Mo
```

```
Read time with index: 0.00571s
Number of records: 134
Current memory usage is 0.16058921813964844Mo; Peak was 0.36258697509765625Mo
replication factor = 1
Create Time: 13.909088 seconds
Current memory usage is 4.802090644836426Mo; Peak was 4.946524620056152Mo
Read time with index: 0.00532s
Number of records: 134
Current memory usage is 0.1622905731201172Mo; Peak was 0.36287689208984375Mo
replication factor = 1
Create Time: 13.986842 seconds
Current memory usage is 4.810091972351074Mo; Peak was 4.9436445236206055Mo
Read time with index: 0.00551s
Number of records: 134
Current memory usage is 0.1636638641357422Mo; Peak was 0.36483001708984375Mo
replication factor = 1
Create Time: 14.054076 seconds
Current memory usage is 4.861987113952637Mo; Peak was 4.963009834289551Mo
Read time with index: 0.00569s
Number of records: 134
Current memory usage is 0.15952110290527344Mo; Peak was 0.36685943603515625Mo
replication factor = 1
Create Time: 14.019309 seconds
Current memory usage is 4.924859046936035Mo; Peak was 4.948177337646484Mo
Update time with index: 0.04665s
Current memory usage is 0.11382389068603516Mo; Peak was 0.1666736602783203Mo
replication factor = 1
Create Time: 13.899656 seconds
Current memory usage is 4.837789535522461Mo; Peak was 4.942084312438965Mo
Update time with index: 0.04846s
Current memory usage is 0.07211017608642578Mo; Peak was 0.17021942138671875Mo
replication factor = 1
Create Time: 14.102795 seconds
Current memory usage is 4.924701690673828Mo; Peak was 4.936135292053223Mo
Update time with index: 0.04815s
Current memory usage is 0.115814208984375Mo; Peak was 0.16515254974365234Mo
replication factor = 1
Create Time: 14.009522 seconds
Current memory usage is 4.869017601013184Mo; Peak was 4.939157485961914Mo
Update time with index: 0.08235s
Current memory usage is 0.14009475708007812Mo; Peak was 0.19379329681396484Mo
replication factor = 1
Create Time: 13.911138 seconds
Current memory usage is 4.905664443969727Mo; Peak was 4.948266983032227Mo
Update time with index: 0.04781s
Current memory usage is 0.10303497314453125Mo; Peak was 0.1685495376586914Mo
replication factor = 1
Create Time: 13.866018 seconds
```

```
Current memory usage is 4.767544746398926Mo; Peak was 4.934412956237793Mo
Delete time with index: 0.04837s
Current memory usage is 0.1604595184326172Mo; Peak was 0.16686153411865234Mo
replication factor = 1
Create Time: 13.953422 seconds
Current memory usage is 4.885368347167969Mo; Peak was 4.958438873291016Mo
Delete time with index: 0.04786s
Current memory usage is 0.10357475280761719Mo; Peak was 0.16515064239501953Mo
replication factor = 1
Create Time: 13.964751 seconds
Current memory usage is 4.776557922363281Mo; Peak was 4.9401655197143555Mo
Delete time with index: 0.04760s
Current memory usage is 0.1595478057861328Mo; Peak was 0.16738033294677734Mo
replication factor = 1
Create Time: 13.836982 seconds
Current memory usage is 4.853072166442871Mo; Peak was 4.9398040771484375Mo
Delete time with index: 0.04810s
Current memory usage is 0.10182380676269531Mo; Peak was 0.16607952117919922Mo
replication factor = 1
Create Time: 13.929552 seconds
Current memory usage is 4.798974990844727Mo; Peak was 4.954037666320801Mo
Delete time with index: 0.04787s
Current memory usage is 0.16366863250732422Mo; Peak was 0.16740798950195312Mo
```

[45]:
```
# 2 replicas
# --- CREATE ---
create_cassandra_large_mean_time_2_index,␣
 ↪create_cassandra_large_std_time_2_index, \
    create_cassandra_large_mean_current_memory_2_index,␣
 ↪create_cassandra_large_std_current_memory_2_index, \
       create_cassandra_large_mean_peak_memory_2_index,␣
 ↪create_cassandra_large_std_peak_memory_2_index =␣
 ↪benchmark_operation(cassandra_insert_index, large_df, 2)

# --- READ ---
read_cassandra_large_mean_time_2_index, read_cassandra_large_std_time_2_index, \
    read_cassandra_large_mean_current_memory_2_index,␣
 ↪read_cassandra_large_std_current_memory_2_index, \
       read_cassandra_large_mean_peak_memory_2_index,␣
 ↪read_cassandra_large_std_peak_memory_2_index =␣
 ↪benchmark_operation(cassandra_read_index, large_df, 2)

# --- UPDATE ---
update_cassandra_large_mean_time_2_index,␣
 ↪update_cassandra_large_std_time_2_index, \
    update_cassandra_large_mean_current_memory_2_index,␣
 ↪update_cassandra_large_std_current_memory_2_index, \
```

```
        update_cassandra_large_mean_peak_memory_2_index,␣
  ↪update_cassandra_large_std_peak_memory_2_index =␣
  ↪benchmark_operation(cassandra_update_index, large_df, 2)

# --- DELETE ---
delete_cassandra_large_mean_time_2_index,␣
  ↪delete_cassandra_large_std_time_2_index, \
     delete_cassandra_large_mean_current_memory_2_index,␣
  ↪delete_cassandra_large_std_current_memory_2_index, \
        delete_cassandra_large_mean_peak_memory_2_index,␣
  ↪delete_cassandra_large_std_peak_memory_2_index =␣
  ↪benchmark_operation(cassandra_delete_index, large_df, 2)
```

```
replication factor = 2
Create Time: 13.920843 seconds
Current memory usage is 4.897453308105469Mo; Peak was 4.943772315979004Mo
replication factor = 2
Create Time: 13.890707 seconds
Current memory usage is 4.896150588989258Mo; Peak was 4.947893142700195Mo
replication factor = 2
Create Time: 13.919407 seconds
Current memory usage is 4.868396759033203Mo; Peak was 4.950902938842773Mo
replication factor = 2
Create Time: 13.856072 seconds
Current memory usage is 4.8690900802612305Mo; Peak was 4.965764999389648Mo
replication factor = 2
Create Time: 13.788314 seconds
Current memory usage is 4.881504058837891Mo; Peak was 4.946169853210449Mo
replication factor = 2
Create Time: 13.869782 seconds
Current memory usage is 4.840914726257324Mo; Peak was 4.954320907592773Mo
Read time with index: 0.00550s
Number of records: 134
Current memory usage is 0.16457176208496094Mo; Peak was 0.36568450927734375Mo
replication factor = 2
Create Time: 13.991386 seconds
Current memory usage is 4.86701774597168Mo; Peak was 4.949618339538574Mo
Read time with index: 0.00567s
Number of records: 134
Current memory usage is 0.1589488983154297Mo; Peak was 0.36685943603515625Mo
replication factor = 2
Create Time: 14.292644 seconds
Current memory usage is 4.55891227722168Mo; Peak was 4.896313667297363Mo
Read time with index: 0.00541s
Number of records: 134
Current memory usage is 0.16594886779785156Mo; Peak was 0.3656806945800781Mo
replication factor = 2
```

```
Create Time: 14.070422 seconds
Current memory usage is 4.904653549194336Mo; Peak was 4.95090389251709Mo
Read time with index: 0.00575s
Number of records: 134
Current memory usage is 0.1596279144287109 4Mo; Peak was 0.364990234375Mo
replication factor = 2
Create Time: 14.072867 seconds
Current memory usage is 4.810305595397949Mo; Peak was 4.977208137512207Mo
Read time with index: 0.00545s
Number of records: 134
Current memory usage is 0.16307640075683594Mo; Peak was 0.36309051513671875Mo
replication factor = 2
Create Time: 13.948846 seconds
Current memory usage is 4.857756614685059Mo; Peak was 4.949367523193359Mo
Update time with index: 0.04842s
Current memory usage is 0.083709716796875Mo; Peak was 0.17891979217529297Mo
replication factor = 2
Create Time: 14.852704 seconds
Current memory usage is 4.925389289855957Mo; Peak was 4.935869216918945Mo
Update time with index: 0.05035s
Current memory usage is 0.11373329162597656Mo; Peak was 0.1680440902709961Mo
replication factor = 2
Create Time: 14.171067 seconds
Current memory usage is 4.783148765563965Mo; Peak was 4.9398040771484375Mo
Update time with index: 0.04832s
Current memory usage is 0.06527137756347656Mo; Peak was 0.17218494415283203Mo
replication factor = 2
Create Time: 13.840303 seconds
Current memory usage is 4.858390808105469Mo; Peak was 4.935758590698242Mo
Update time with index: 0.04805s
Current memory usage is 0.10092544555664062Mo; Peak was 0.16543292999267578Mo
replication factor = 2
Create Time: 13.959407 seconds
Current memory usage is 4.76158332824707Mo; Peak was 4.937702178955078Mo
Update time with index: 0.04901s
Current memory usage is 0.1452169418334961Mo; Peak was 0.167938232421875Mo
replication factor = 2
Create Time: 13.993000 seconds
Current memory usage is 4.869877815246582Mo; Peak was 4.957143783569336Mo
Delete time with index: 0.05991s
Current memory usage is 0.09912300109863281Mo; Peak was 0.16388225555419922Mo
replication factor = 2
Create Time: 14.026389 seconds
Current memory usage is 4.7885026931762695Mo; Peak was 4.939507484436035Mo
Delete time with index: 0.04832s
Current memory usage is 0.16923046112060547Mo; Peak was 0.17296981811523438Mo
replication factor = 2
Create Time: 14.072506 seconds
```

```
Current memory usage is 4.864941596984863Mo; Peak was 4.943078994750977Mo
Delete time with index: 0.04798s
Current memory usage is 0.10161018371582031Mo; Peak was 0.16687297821044922Mo
replication factor = 2
Create Time: 13.843135 seconds
Current memory usage is 4.78692626953125Mo; Peak was 4.934713363647461Mo
Delete time with index: 0.04779s
Current memory usage is 0.17072582244873047Mo; Peak was 0.17446517944335938Mo
replication factor = 2
Create Time: 14.128505 seconds
Current memory usage is 4.849532127380371Mo; Peak was 4.937151908874512Mo
Delete time with index: 0.04723s
Current memory usage is 0.10156440734863281Mo; Peak was 0.16682720184326172Mo
```

[46]:
```
# 5 replicas
# --- CREATE ---
create_cassandra_large_mean_time_5_index,␣
 ↪create_cassandra_large_std_time_5_index, \
    create_cassandra_large_mean_current_memory_5_index,␣
 ↪create_cassandra_large_std_current_memory_5_index, \
       create_cassandra_large_mean_peak_memory_5_index,␣
 ↪create_cassandra_large_std_peak_memory_5_index =␣
 ↪benchmark_operation(cassandra_insert_index, large_df, 5)

# --- READ ---
read_cassandra_large_mean_time_5_index, read_cassandra_large_std_time_5_index, \
    read_cassandra_large_mean_current_memory_5_index,␣
 ↪read_cassandra_large_std_current_memory_5_index, \
       read_cassandra_large_mean_peak_memory_5_index,␣
 ↪read_cassandra_large_std_peak_memory_5_index =␣
 ↪benchmark_operation(cassandra_read_index, large_df, 5)

# --- UPDATE ---
update_cassandra_large_mean_time_5_index,␣
 ↪update_cassandra_large_std_time_5_index, \
    update_cassandra_large_mean_current_memory_5_index,␣
 ↪update_cassandra_large_std_current_memory_5_index, \
       update_cassandra_large_mean_peak_memory_5_index,␣
 ↪update_cassandra_large_std_peak_memory_5_index =␣
 ↪benchmark_operation(cassandra_update_index, large_df, 5)

# --- DELETE ---
delete_cassandra_large_mean_time_5_index,␣
 ↪delete_cassandra_large_std_time_5_index, \
    delete_cassandra_large_mean_current_memory_5_index,␣
 ↪delete_cassandra_large_std_current_memory_5_index, \
```

```
      delete_cassandra_large_mean_peak_memory_5_index,␣
↪delete_cassandra_large_std_peak_memory_5_index =␣
↪benchmark_operation(cassandra_delete_index, large_df, 5)
```

```
replication factor = 5
Create Time: 13.930577 seconds
Current memory usage is 4.801914215087891Mo; Peak was 4.939885139465332Mo
replication factor = 5
Create Time: 13.984756 seconds
Current memory usage is 4.717752456665039Mo; Peak was 4.80078125Mo
replication factor = 5
Create Time: 13.963705 seconds
Current memory usage is 4.856592178344727Mo; Peak was 4.939035415649414Mo
replication factor = 5
Create Time: 13.845536 seconds
Current memory usage is 4.820783615112305Mo; Peak was 4.944430351257324Mo
replication factor = 5
Create Time: 13.844769 seconds
Current memory usage is 4.823464393615723Mo; Peak was 4.938815116882324Mo
replication factor = 5
Create Time: 13.975929 seconds
Current memory usage is 4.78032112121582Mo; Peak was 4.946612358093262Mo
Read time with index: 0.00546s
Number of records: 134
Current memory usage is 0.16246604919433594Mo; Peak was 0.3620758056640625Mo
replication factor = 5
Create Time: 13.987159 seconds
Current memory usage is 4.802323341369629Mo; Peak was 4.949580192565918Mo
Read time with index: 0.00541s
Number of records: 134
Current memory usage is 0.1636638641357422Mo; Peak was 0.36461639404296875Mo
replication factor = 5
Create Time: 14.093941 seconds
Current memory usage is 4.886354446411133Mo; Peak was 4.96112060546875Mo
Read time with index: 0.00573s
Number of records: 134
Current memory usage is 0.16376304626464844Mo; Peak was 0.366485595703125Mo
replication factor = 5
Create Time: 14.021213 seconds
Current memory usage is 4.921138763427734Mo; Peak was 4.967630386352539Mo
Read time with index: 0.00572s
Number of records: 134
Current memory usage is 0.15976524353027344Mo; Peak was 0.36621856689453125Mo
replication factor = 5
Create Time: 14.027654 seconds
Current memory usage is 4.781538009643555Mo; Peak was 4.950850486755371Mo
Read time with index: 0.00546s
Number of records: 134
```

```
Current memory usage is 0.1626758575439453Mo; Peak was 0.3626899719238281Mo
replication factor = 5
Create Time: 13.886383 seconds
Current memory usage is 4.794289588928223Mo; Peak was 4.955617904663086Mo
Update time with index: 0.04846s
Current memory usage is 0.1714305877685547Mo; Peak was 0.1751699447631836Mo
replication factor = 5
Create Time: 14.060625 seconds
Current memory usage is 4.845602989196777Mo; Peak was 4.936674118041992Mo
Update time with index: 0.04858s
Current memory usage is 0.10201263427734375Mo; Peak was 0.1664133071899414Mo
replication factor = 5
Create Time: 13.984732 seconds
Current memory usage is 4.796521186828613Mo; Peak was 4.945964813232422Mo
Update time with index: 0.04853s
Current memory usage is 0.07068634033203125Mo; Peak was 0.17475509643554688Mo
replication factor = 5
Create Time: 14.028229 seconds
Current memory usage is 4.846238136291504Mo; Peak was 4.933637619018555Mo
Update time with index: 0.04831s
Current memory usage is 0.1009674072265625Mo; Peak was 0.1664285659790039Mo
replication factor = 5
Create Time: 13.965262 seconds
Current memory usage is 4.776338577270508Mo; Peak was 4.93172550201416Mo
Update time with index: 0.04792s
Current memory usage is 0.1641092300415039Mo; Peak was 0.1678485870361328Mo
replication factor = 5
Create Time: 14.302077 seconds
Current memory usage is 4.644412994384766Mo; Peak was 4.829324722290039Mo
Delete time with index: 0.04975s
Current memory usage is 0.15262985229492188Mo; Peak was 0.18832015991210938Mo
replication factor = 5
Create Time: 14.251046 seconds
Current memory usage is 4.870517730712891Mo; Peak was 4.944635391235352Mo
Delete time with index: 0.04827s
Current memory usage is 0.10073661804199219Mo; Peak was 0.16485881805419922Mo
replication factor = 5
Create Time: 14.053293 seconds
Current memory usage is 4.799773216247559Mo; Peak was 4.942422866821289Mo
Delete time with index: 0.04882s
Current memory usage is 0.06940555572509766Mo; Peak was 0.1759347915649414Mo
replication factor = 5
Create Time: 14.148939 seconds
Current memory usage is 4.867612838745117Mo; Peak was 4.938565254211426Mo
Delete time with index: 0.04813s
Current memory usage is 0.10262107849121094Mo; Peak was 0.1670064926147461Mo
replication factor = 5
Create Time: 14.212442 seconds
```

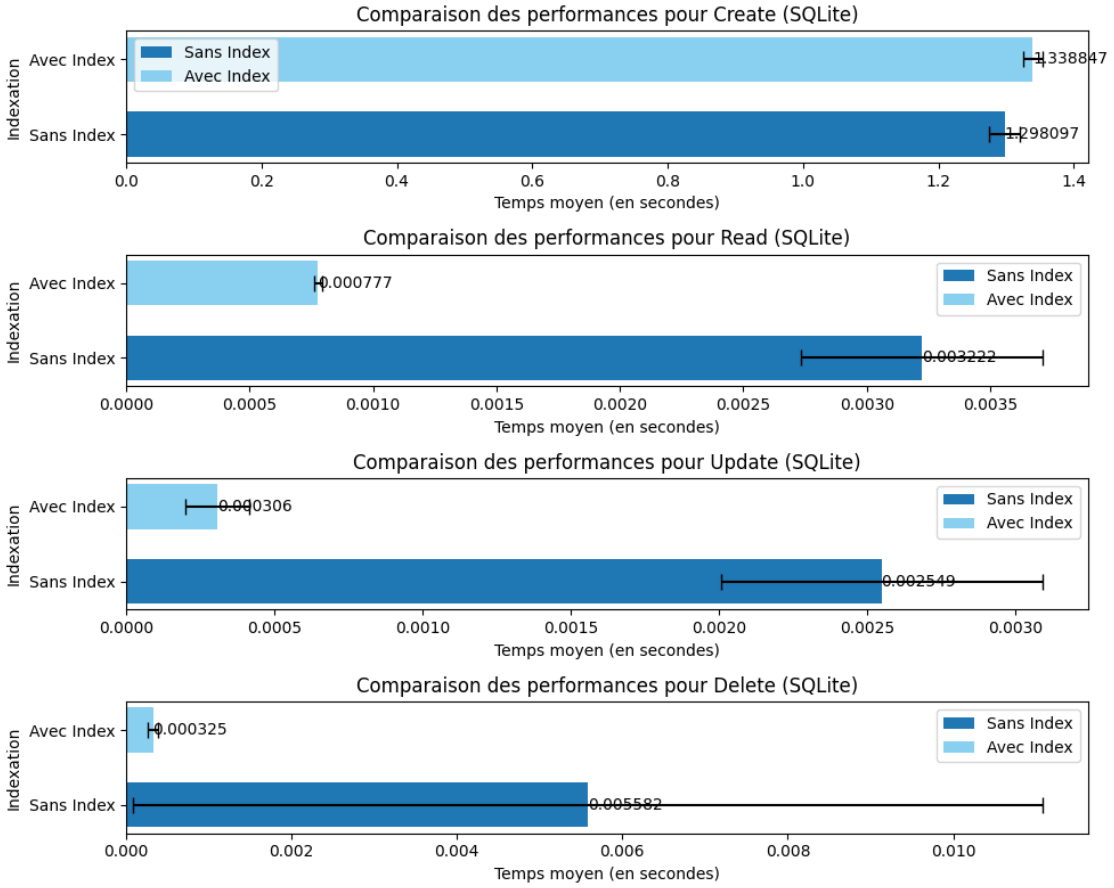
```
Current memory usage is 4.794244766235352Mo; Peak was 4.931845664978027Mo
Delete time with index: 0.04911s
Current memory usage is 0.06717777252197266Mo; Peak was 0.1737070083618164Mo
```

4.0.2 Visualisation

Comparaison des temps avec et sans index

[47]:
```
# Temps moyens par actions pour SQLite avec et sans index
actions = ['Create', 'Read', 'Update', 'Delete']

mean_without_index = [create_sqlite_large_mean_time,␣
 ↪read_sqlite_large_mean_time,
                      update_sqlite_large_mean_time,␣
 ↪delete_sqlite_large_mean_time]
mean_with_index = [create_sqlite_large_mean_time_index,␣
 ↪read_sqlite_large_mean_time_index,
                   update_sqlite_large_mean_time_index,␣
 ↪delete_sqlite_large_mean_time_index]

std_without_index = [create_sqlite_large_std_time, read_sqlite_large_std_time,
                     update_sqlite_large_std_time, delete_sqlite_large_std_time]
std_with_index = [create_sqlite_large_std_time_index,␣
 ↪read_sqlite_large_std_time_index,
                  update_sqlite_large_std_time_index,␣
 ↪delete_sqlite_large_std_time_index]

fig, axes = plt.subplots(4, 1, figsize=(10, 8))
width = 0.6

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(2)
    mean_values = [mean_without_index[i], mean_with_index[i]]
    std_values = [std_without_index[i], std_with_index[i]]

    bars1 = ax.barh(x[0], mean_values[0], width, xerr=std_values[0],␣
 ↪label='Sans Index', capsize=5, color='tab:blue')
    bars2 = ax.barh(x[1], mean_values[1], width, xerr=std_values[1],␣
 ↪label='Avec Index', capsize=5, color='#89CFF0')

    ax.set_xlabel('Temps moyen (en secondes)')
    ax.set_ylabel('Indexation')
    ax.set_title(f'Comparaison des performances pour {action} (SQLite)')
    ax.set_yticks(x)
    ax.set_yticklabels(['Sans Index', 'Avec Index'])
    ax.legend()
```

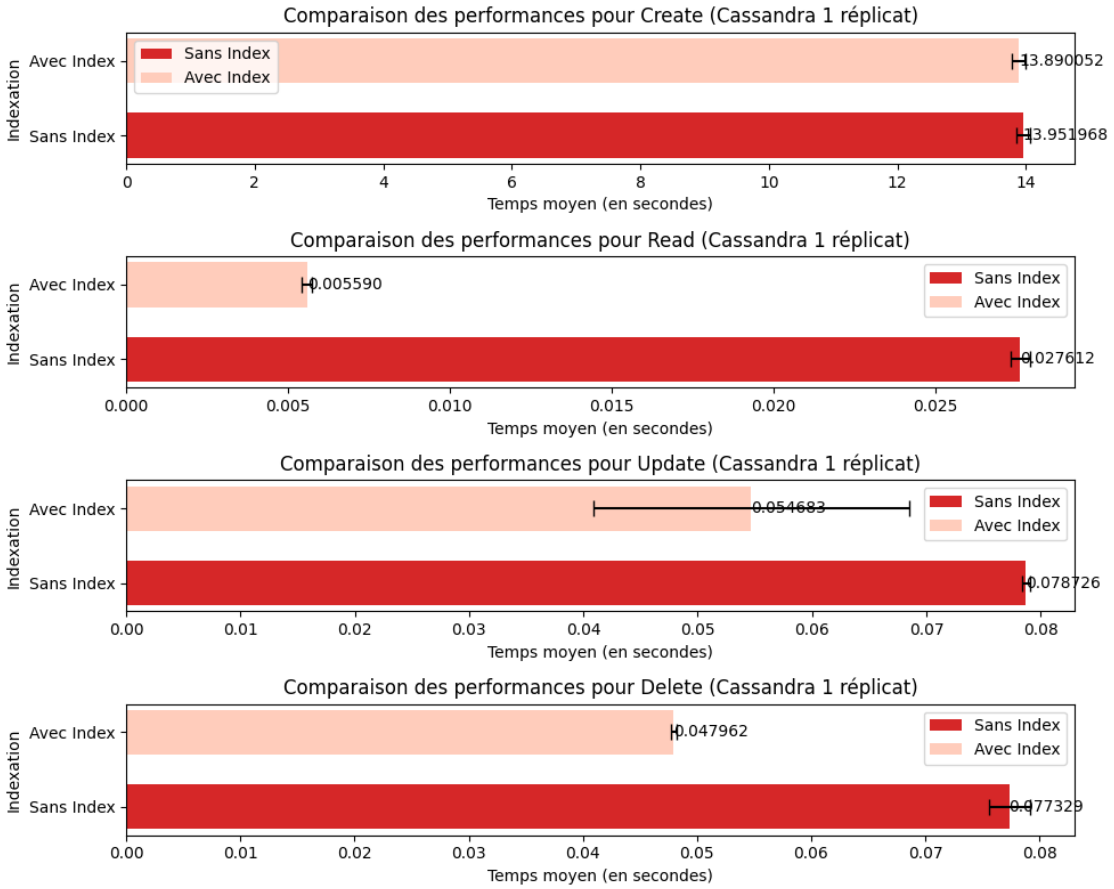
```
    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
 ↪va='center', ha='left')

    add_values(bars1)
    add_values(bars2)

plt.tight_layout()
plt.show()
```



[48]:
```
# Temps moyens par actions pour Cassandra avec et sans index
# 1 replica
actions = ['Create', 'Read', 'Update', 'Delete']

mean_without_index = [create_cassandra_large_mean_time,␣
 ↪read_cassandra_large_mean_time,
```

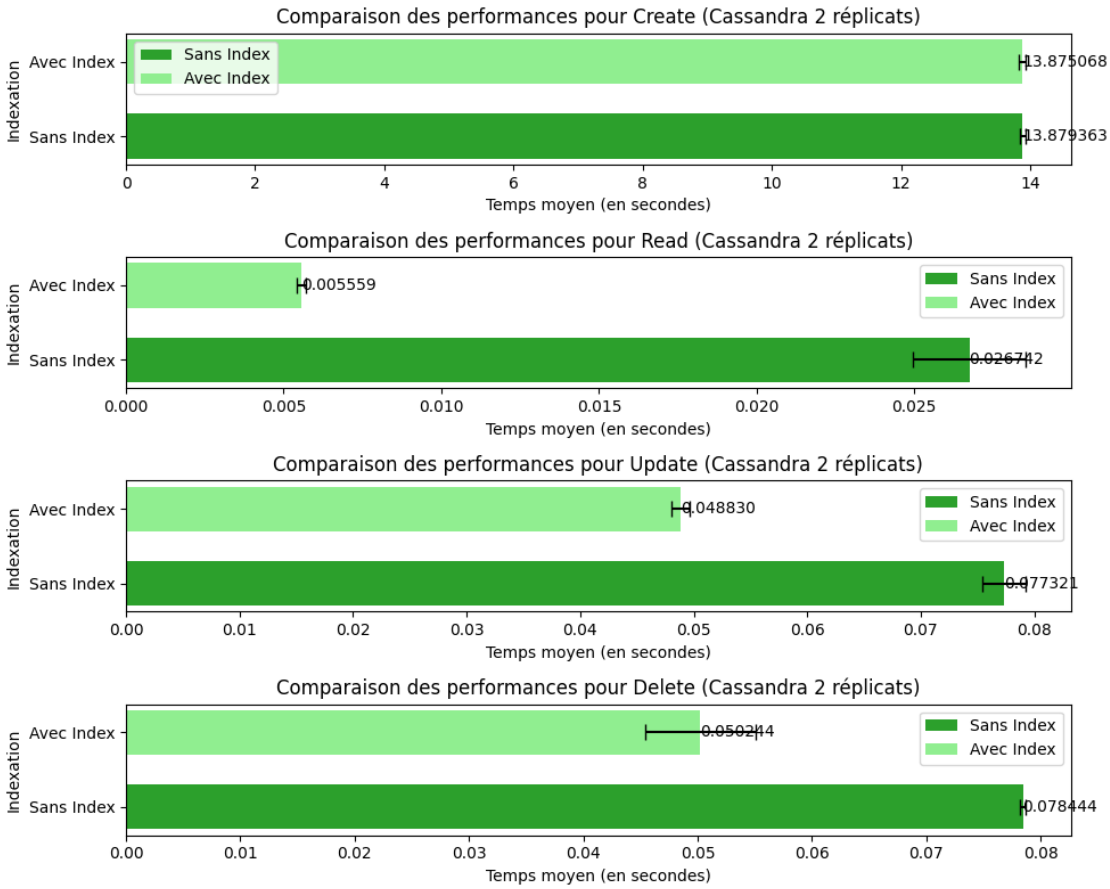
```
                      update_cassandra_large_mean_time,␣
 ↪delete_cassandra_large_mean_time]
mean_with_index = [create_cassandra_large_mean_time_index,␣
 ↪read_cassandra_large_mean_time_index,
                   update_cassandra_large_mean_time_index,␣
 ↪delete_cassandra_large_mean_time_index]

std_without_index = [create_cassandra_large_std_time,␣
 ↪read_cassandra_large_std_time,
                     update_cassandra_large_std_time,␣
 ↪delete_cassandra_large_std_time]
std_with_index = [create_cassandra_large_std_time_index,␣
 ↪read_cassandra_large_std_time_index,
                  update_cassandra_large_std_time_index,␣
 ↪delete_cassandra_large_std_time_index]

fig, axes = plt.subplots(4, 1, figsize=(10, 8))
width = 0.6

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(2)
    mean_values = [mean_without_index[i], mean_with_index[i]]
    std_values = [std_without_index[i], std_with_index[i]]

    bars1 = ax.barh(x[0], mean_values[0], width, xerr=std_values[0],␣
 ↪label='Sans Index', capsize=5, color='tab:red')
    bars2 = ax.barh(x[1], mean_values[1], width, xerr=std_values[1],␣
 ↪label='Avec Index', capsize=5, color='#FFCCBB')

    ax.set_xlabel('Temps moyen (en secondes)')
    ax.set_ylabel('Indexation')
    ax.set_title(f'Comparaison des performances pour {action} (Cassandra 1␣
 ↪réplicat)')
    ax.set_yticks(x)
    ax.set_yticklabels(['Sans Index', 'Avec Index'])
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
 ↪va='center', ha='left')

    add_values(bars1)
    add_values(bars2)
```

```
plt.tight_layout()
plt.show()
```



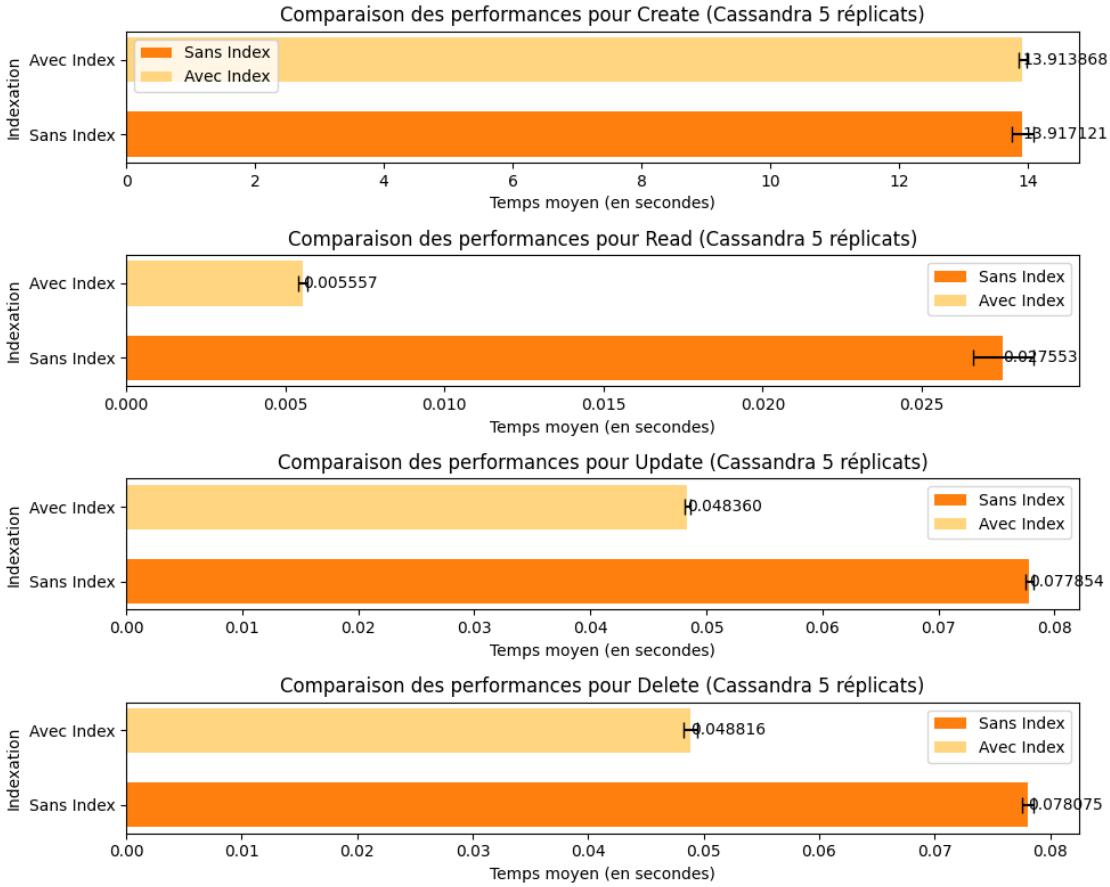
[49]:
```
# Temps moyens par actions pour Cassandra avec et sans index
# 2 replicas
actions = ['Create', 'Read', 'Update', 'Delete']

mean_without_index = [create_cassandra_large_mean_time_2,␣
 ↪read_cassandra_large_mean_time_2,
                      update_cassandra_large_mean_time_2,␣
 ↪delete_cassandra_large_mean_time_2]
mean_with_index = [create_cassandra_large_mean_time_2_index,␣
 ↪read_cassandra_large_mean_time_2_index,
                   update_cassandra_large_mean_time_2_index,␣
 ↪delete_cassandra_large_mean_time_2_index]
```

```
std_without_index = [create_cassandra_large_std_time_2,␣
 ↪read_cassandra_large_std_time_2,
                     update_cassandra_large_std_time_2,␣
 ↪delete_cassandra_large_std_time_2]
std_with_index = [create_cassandra_large_std_time_2_index,␣
 ↪read_cassandra_large_std_time_2_index,
                  update_cassandra_large_std_time_2_index,␣
 ↪delete_cassandra_large_std_time_2_index]

fig, axes = plt.subplots(4, 1, figsize=(10, 8))
width = 0.6

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(2)
    mean_values = [mean_without_index[i], mean_with_index[i]]
    std_values = [std_without_index[i], std_with_index[i]]

    bars1 = ax.barh(x[0], mean_values[0], width, xerr=std_values[0],␣
 ↪label='Sans Index', capsize=5, color='tab:green')
    bars2 = ax.barh(x[1], mean_values[1], width, xerr=std_values[1],␣
 ↪label='Avec Index', capsize=5, color='#90EE90')

    ax.set_xlabel('Temps moyen (en secondes)')
    ax.set_ylabel('Indexation')
    ax.set_title(f'Comparaison des performances pour {action} (Cassandra 2␣
 ↪réplicats)')
    ax.set_yticks(x)
    ax.set_yticklabels(['Sans Index', 'Avec Index'])
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
 ↪va='center', ha='left')

    add_values(bars1)
    add_values(bars2)

plt.tight_layout()
plt.show()
```



[50]:
```
# Temps moyens par actions pour Cassandra avec et sans index
# 5 replicas
actions = ['Create', 'Read', 'Update', 'Delete']

mean_without_index = [create_cassandra_large_mean_time_5,␣
 ↪read_cassandra_large_mean_time_5,
                      update_cassandra_large_mean_time_5,␣
 ↪delete_cassandra_large_mean_time_5]
mean_with_index = [create_cassandra_large_mean_time_5_index,␣
 ↪read_cassandra_large_mean_time_5_index,
                   update_cassandra_large_mean_time_5_index,␣
 ↪delete_cassandra_large_mean_time_5_index]


std_without_index = [create_cassandra_large_std_time_5,␣
 ↪read_cassandra_large_std_time_5,
                     update_cassandra_large_std_time_5,␣
 ↪delete_cassandra_large_std_time_5]
```

```
std_with_index = [create_cassandra_large_std_time_5_index,␣
 ↪read_cassandra_large_std_time_5_index,
                  update_cassandra_large_std_time_5_index,␣
 ↪delete_cassandra_large_std_time_5_index]

fig, axes = plt.subplots(4, 1, figsize=(10, 8))
width = 0.6

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(2)
    mean_values = [mean_without_index[i], mean_with_index[i]]
    std_values = [std_without_index[i], std_with_index[i]]

    bars1 = ax.barh(x[0], mean_values[0], width, xerr=std_values[0],␣
 ↪label='Sans Index', capsize=5, color='tab:orange')
    bars2 = ax.barh(x[1], mean_values[1], width, xerr=std_values[1],␣
 ↪label='Avec Index', capsize=5, color='#FFD580')

    ax.set_xlabel('Temps moyen (en secondes)')
    ax.set_ylabel('Indexation')
    ax.set_title(f'Comparaison des performances pour {action} (Cassandra 5␣
 ↪réplicats)')
    ax.set_yticks(x)
    ax.set_yticklabels(['Sans Index', 'Avec Index'])
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.6f}',␣
 ↪va='center', ha='left')

    add_values(bars1)
    add_values(bars2)

plt.tight_layout()
plt.show()
```

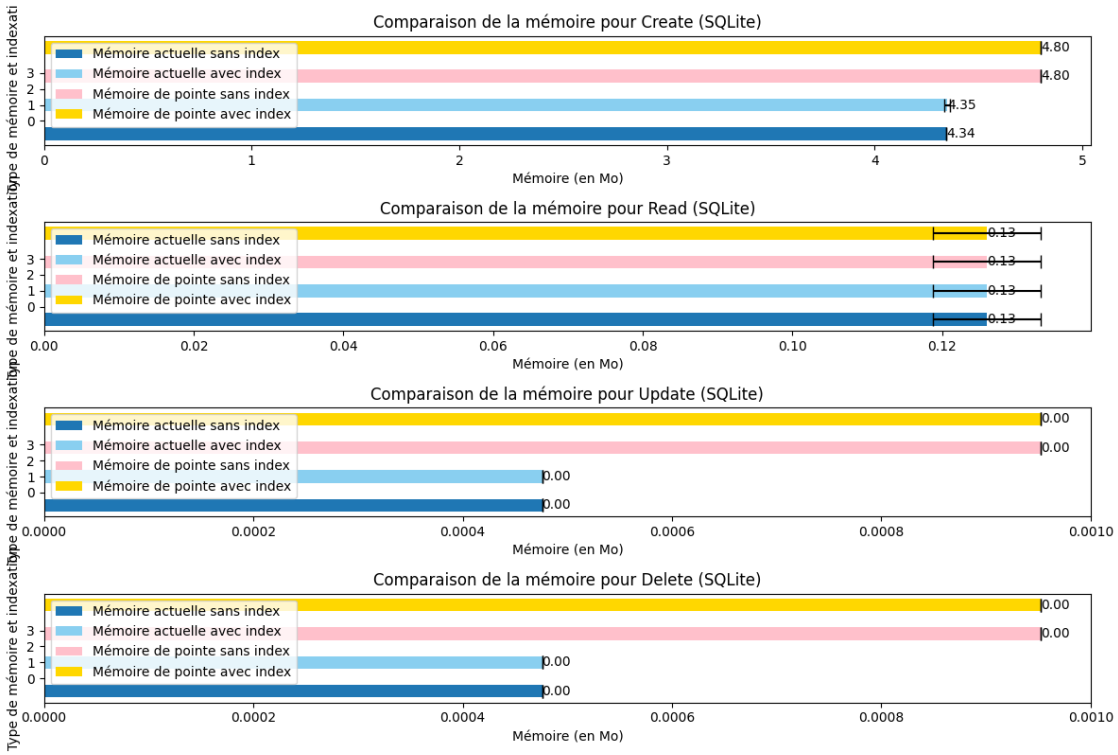


Comparaison de la mémoire avec et sans les index

[ ]:
```
# Mémoire par actions pour SQLite avec et sans index
actions = ['Create', 'Read', 'Update', 'Delete']

mean_current_without_index = [create_sqlite_large_mean_current_memory,␣
 ↪read_sqlite_large_mean_current_memory,
                              update_sqlite_large_mean_current_memory,␣
 ↪delete_sqlite_large_mean_current_memory]
mean_current_with_index = [create_sqlite_large_mean_current_memory_index,␣
 ↪read_sqlite_large_mean_current_memory_index,
                           update_sqlite_large_mean_current_memory_index,␣
 ↪delete_sqlite_large_mean_current_memory_index]
std_current_without_index = [create_sqlite_large_std_current_memory,␣
 ↪read_sqlite_large_std_current_memory,
                             update_sqlite_large_std_current_memory,␣
 ↪delete_sqlite_large_std_current_memory]
std_current_with_index = [create_sqlite_large_std_current_memory_index,␣
 ↪read_sqlite_large_std_current_memory_index,
```

```
                          update_sqlite_large_std_current_memory_index,␣
 ↪delete_sqlite_large_std_current_memory_index]

mean_peak_without_index = [create_sqlite_large_mean_peak_memory,␣
 ↪read_sqlite_large_mean_peak_memory,
                           update_sqlite_large_mean_peak_memory,␣
 ↪delete_sqlite_large_mean_peak_memory]
mean_peak_with_index = [create_sqlite_large_mean_peak_memory_index,␣
 ↪read_sqlite_large_mean_peak_memory_index,
                        update_sqlite_large_mean_peak_memory_index,␣
 ↪delete_sqlite_large_mean_peak_memory_index]
std_peak_without_index = [create_sqlite_large_std_peak_memory,␣
 ↪read_sqlite_large_std_peak_memory,
                          update_sqlite_large_std_peak_memory,␣
 ↪delete_sqlite_large_std_peak_memory]
std_peak_with_index = [create_sqlite_large_std_peak_memory_index,␣
 ↪read_sqlite_large_std_peak_memory_index,
                       update_sqlite_large_std_peak_memory_index,␣
 ↪delete_sqlite_large_std_peak_memory_index]

fig, axes = plt.subplots(4, 1, figsize=(12, 8))
width = 0.8

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(4)  # 4 barres par graphique : Mem actuelle sans index, Mem␣
 ↪actuelle avec index, Mem de pointe sans index, Mem de pointe avec index
    mean_values = [mean_current_without_index[i], mean_current_with_index[i],␣
 ↪mean_peak_without_index[i], mean_peak_with_index[i]]
    std_values = [std_current_without_index[i], std_current_with_index[i],␣
 ↪std_peak_without_index[i], std_peak_with_index[i]]

    bars_current_without = ax.barh(x[0] - width, mean_values[0], width,␣
 ↪xerr=std_values[0], label='Mémoire actuelle sans index', capsize=5,␣
 ↪color='tab:blue')
    bars_current_with = ax.barh(x[1], mean_values[1], width,␣
 ↪xerr=std_values[1], label='Mémoire actuelle avec index', capsize=5,␣
 ↪color='#89CFF0')
    bars_peak_without = ax.barh(x[2] + width, mean_values[2], width,␣
 ↪xerr=std_values[2], label='Mémoire de pointe sans index', capsize=5,␣
 ↪color='pink')
    bars_peak_with = ax.barh(x[3] + 2 * width, mean_values[3], width,␣
 ↪xerr=std_values[3], label='Mémoire de pointe avec index', capsize=5,␣
 ↪color='gold')

    ax.set_xlabel('Mémoire (en Mo)')
```

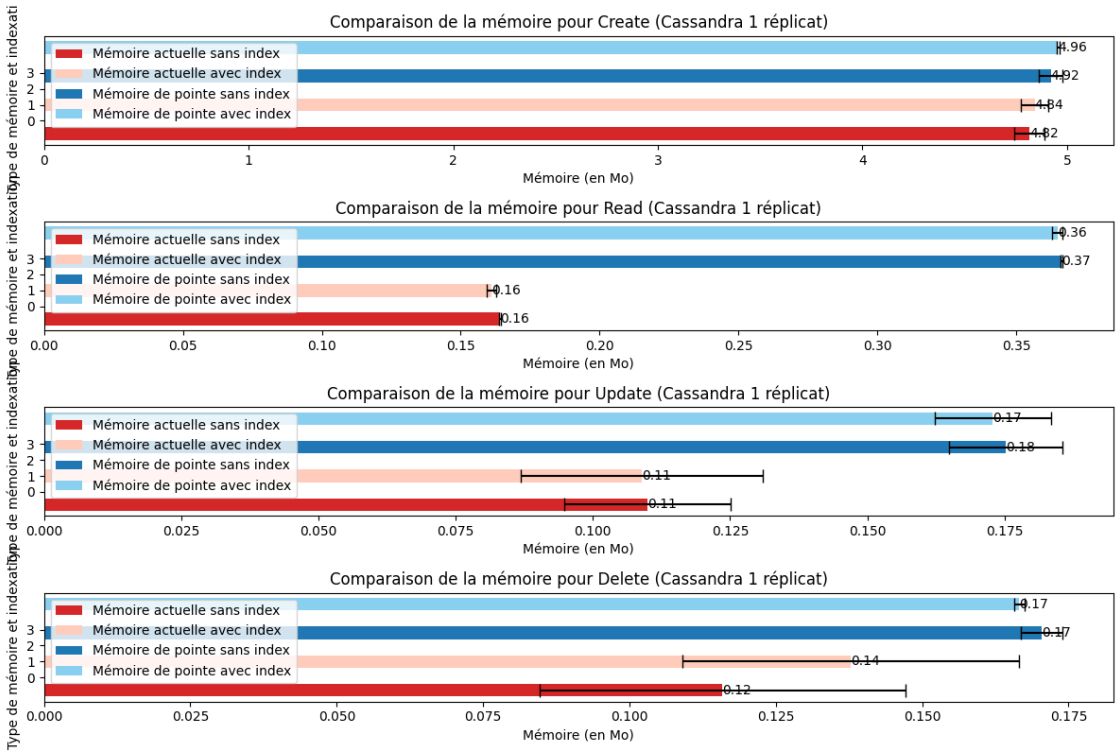
```
    ax.set_ylabel('Type de mémoire et indexation')
    ax.set_title(f'Comparaison de la mémoire pour {action} (SQLite)')
    ax.set_yticks(x)
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.2f}',␣
 ↪va='center', ha='left')

    add_values(bars_current_without)
    add_values(bars_current_with)
    add_values(bars_peak_without)
    add_values(bars_peak_with)

plt.tight_layout()
plt.show()
```



[52]:
```
# Mémoire par actions pour Cassandra avec et sans index
# 1 replica
actions = ['Create', 'Read', 'Update', 'Delete']
```

```
mean_current_without_index = [create_cassandra_large_mean_current_memory,␣
 ↪read_cassandra_large_mean_current_memory,
                               update_cassandra_large_mean_current_memory,␣
 ↪delete_cassandra_large_mean_current_memory]
mean_current_with_index = [create_cassandra_large_mean_current_memory_index,␣
 ↪read_cassandra_large_mean_current_memory_index,
                            update_cassandra_large_mean_current_memory_index,␣
 ↪delete_cassandra_large_mean_current_memory_index]
std_current_without_index = [create_cassandra_large_std_current_memory,␣
 ↪read_cassandra_large_std_current_memory,
                              update_cassandra_large_std_current_memory,␣
 ↪delete_cassandra_large_std_current_memory]
std_current_with_index = [create_cassandra_large_std_current_memory_index,␣
 ↪read_cassandra_large_std_current_memory_index,
                           update_cassandra_large_std_current_memory_index,␣
 ↪delete_cassandra_large_std_current_memory_index]

mean_peak_without_index = [create_cassandra_large_mean_peak_memory,␣
 ↪read_cassandra_large_mean_peak_memory,
                            update_cassandra_large_mean_peak_memory,␣
 ↪delete_cassandra_large_mean_peak_memory]
mean_peak_with_index = [create_cassandra_large_mean_peak_memory_index,␣
 ↪read_cassandra_large_mean_peak_memory_index,
                         update_cassandra_large_mean_peak_memory_index,␣
 ↪delete_cassandra_large_mean_peak_memory_index]
std_peak_without_index = [create_cassandra_large_std_peak_memory,␣
 ↪read_cassandra_large_std_peak_memory,
                           update_cassandra_large_std_peak_memory,␣
 ↪delete_cassandra_large_std_peak_memory]
std_peak_with_index = [create_cassandra_large_std_peak_memory_index,␣
 ↪read_cassandra_large_std_peak_memory_index,
                        update_cassandra_large_std_peak_memory_index,␣
 ↪delete_cassandra_large_std_peak_memory_index]

fig, axes = plt.subplots(4, 1, figsize=(12, 8))
width = 0.8

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(4)  # 4 barres par graphique : Mem actuelle sans index, Mem␣
 ↪actuelle avec index, Mem de pointe sans index, Mem de pointe avec index
    mean_values = [mean_current_without_index[i], mean_current_with_index[i],␣
 ↪mean_peak_without_index[i], mean_peak_with_index[i]]
    std_values = [std_current_without_index[i], std_current_with_index[i],␣
 ↪std_peak_without_index[i], std_peak_with_index[i]]
```

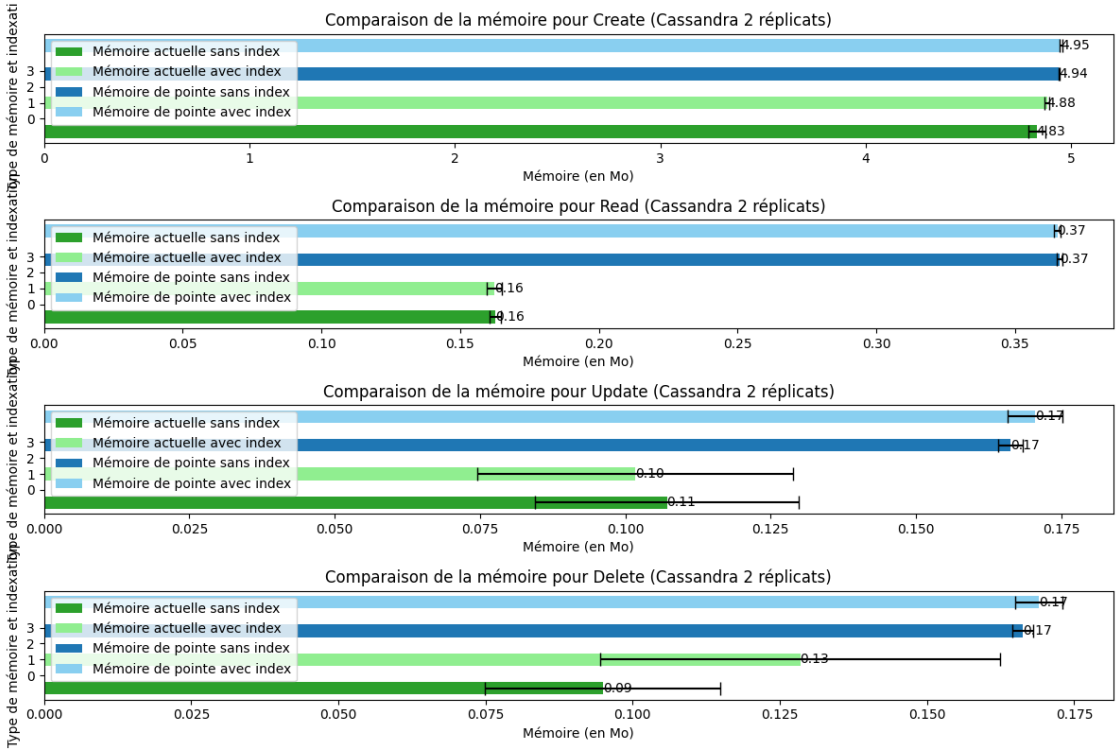
```
    bars_current_without = ax.barh(x[0] - width, mean_values[0], width,␣
↪xerr=std_values[0], label='Mémoire actuelle sans index', capsize=5,␣
↪color='tab:red')
    bars_current_with = ax.barh(x[1], mean_values[1], width,␣
↪xerr=std_values[1], label='Mémoire actuelle avec index', capsize=5,␣
↪color='#FFCCBB')
    bars_peak_without = ax.barh(x[2] + width, mean_values[2], width,␣
↪xerr=std_values[2], label='Mémoire de pointe sans index', capsize=5,␣
↪color='tab:blue')
    bars_peak_with = ax.barh(x[3] + 2 * width, mean_values[3], width,␣
↪xerr=std_values[3], label='Mémoire de pointe avec index', capsize=5,␣
↪color='#89CFF0')

    ax.set_xlabel('Mémoire (en Mo)')
    ax.set_ylabel('Type de mémoire et indexation')
    ax.set_title(f'Comparaison de la mémoire pour {action} (Cassandra 1␣
↪réplicat)')
    ax.set_yticks(x)
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.2f}',␣
↪va='center', ha='left')

    add_values(bars_current_without)
    add_values(bars_current_with)
    add_values(bars_peak_without)
    add_values(bars_peak_with)

plt.tight_layout()
plt.show()
```



[53]:
```
# Mémoire par actions pour Cassandra avec et sans index
# 2 replicas
actions = ['Create', 'Read', 'Update', 'Delete']

mean_current_without_index = [create_cassandra_large_mean_current_memory_2,␣
 ↪read_cassandra_large_mean_current_memory_2,
                              update_cassandra_large_mean_current_memory_2,␣
 ↪delete_cassandra_large_mean_current_memory_2]
mean_current_with_index = [create_cassandra_large_mean_current_memory_2_index,␣
 ↪read_cassandra_large_mean_current_memory_2_index,
                           update_cassandra_large_mean_current_memory_2_index,␣
 ↪delete_cassandra_large_mean_current_memory_2_index]
std_current_without_index = [create_cassandra_large_std_current_memory_2,␣
 ↪read_cassandra_large_std_current_memory_2,
                             update_cassandra_large_std_current_memory_2,␣
 ↪delete_cassandra_large_std_current_memory_2]
std_current_with_index = [create_cassandra_large_std_current_memory_2_index,␣
 ↪read_cassandra_large_std_current_memory_2_index,
                          update_cassandra_large_std_current_memory_2_index,␣
 ↪delete_cassandra_large_std_current_memory_2_index]
```

```
mean_peak_without_index = [create_cassandra_large_mean_peak_memory_2,␣
 ↪read_cassandra_large_mean_peak_memory_2,
                            update_cassandra_large_mean_peak_memory_2,␣
 ↪delete_cassandra_large_mean_peak_memory_2]
mean_peak_with_index =  [create_cassandra_large_mean_peak_memory_2_index,␣
 ↪read_cassandra_large_mean_peak_memory_2_index,
                            update_cassandra_large_mean_peak_memory_2_index,␣
 ↪delete_cassandra_large_mean_peak_memory_2_index]
std_peak_without_index = [create_cassandra_large_std_peak_memory_2,␣
 ↪read_cassandra_large_std_peak_memory_2,
                           update_cassandra_large_std_peak_memory_2,␣
 ↪delete_cassandra_large_std_peak_memory_2]
std_peak_with_index = [create_cassandra_large_std_peak_memory_2_index,␣
 ↪read_cassandra_large_std_peak_memory_2_index,
                           update_cassandra_large_std_peak_memory_2_index,␣
 ↪delete_cassandra_large_std_peak_memory_2_index]

fig, axes = plt.subplots(4, 1, figsize=(12, 8))
width = 0.8

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(4)  # 4 barres par graphique : Mem actuelle sans index, Mem␣
 ↪actuelle avec index, Mem de pointe sans index, Mem de pointe avec index
    mean_values = [mean_current_without_index[i], mean_current_with_index[i],␣
 ↪mean_peak_without_index[i], mean_peak_with_index[i]]
    std_values = [std_current_without_index[i], std_current_with_index[i],␣
 ↪std_peak_without_index[i], std_peak_with_index[i]]

    bars_current_without = ax.barh(x[0] - width, mean_values[0], width,␣
 ↪xerr=std_values[0], label='Mémoire actuelle sans index', capsize=5,␣
 ↪color='tab:green')
    bars_current_with = ax.barh(x[1], mean_values[1], width,␣
 ↪xerr=std_values[1], label='Mémoire actuelle avec index', capsize=5,␣
 ↪color='#90EE90')
    bars_peak_without = ax.barh(x[2] + width, mean_values[2], width,␣
 ↪xerr=std_values[2], label='Mémoire de pointe sans index', capsize=5,␣
 ↪color='tab:blue')
    bars_peak_with = ax.barh(x[3] + 2 * width, mean_values[3], width,␣
 ↪xerr=std_values[3], label='Mémoire de pointe avec index', capsize=5,␣
 ↪color='#89CFF0')

    ax.set_xlabel('Mémoire (en Mo)')
    ax.set_ylabel('Type de mémoire et indexation')
    ax.set_title(f'Comparaison de la mémoire pour {action} (Cassandra 2␣
 ↪réplicats)')
```

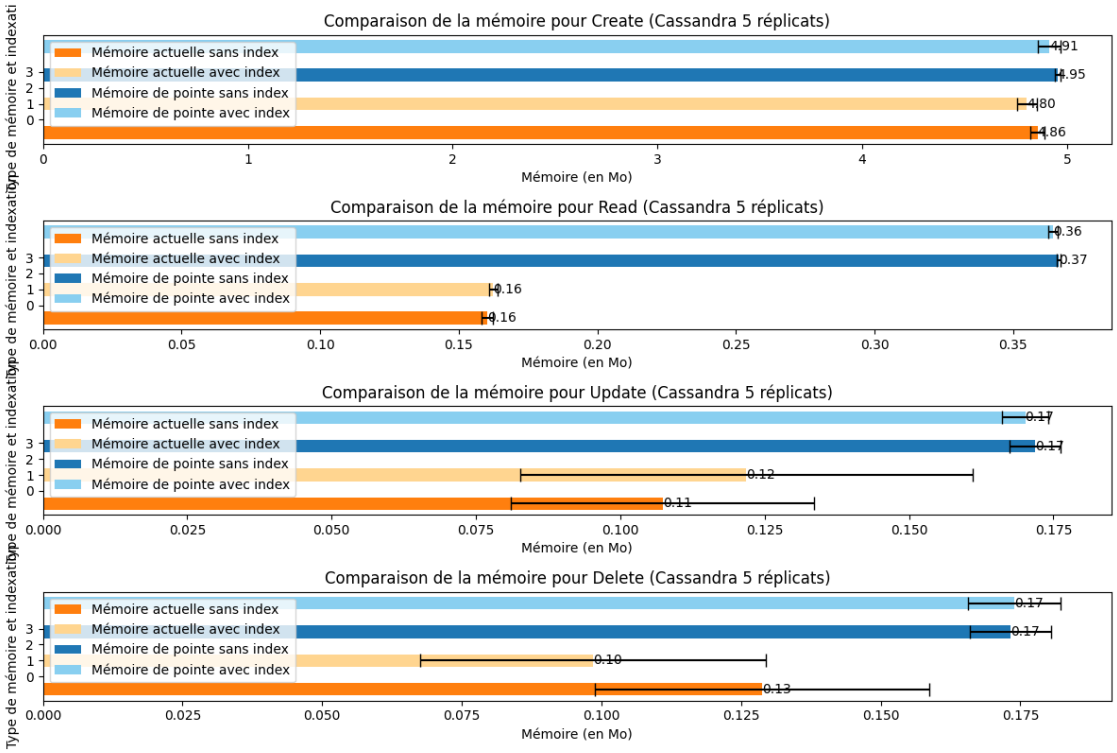
```
    ax.set_yticks(x)
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.2f}',␣
 ↪va='center', ha='left')

    add_values(bars_current_without)
    add_values(bars_current_with)
    add_values(bars_peak_without)
    add_values(bars_peak_with)

plt.tight_layout()
plt.show()
```



[54]:
```
# Mémoire par actions pour Cassandra avec et sans index
# 5 replicas
actions = ['Create', 'Read', 'Update', 'Delete']

mean_current_without_index = [create_cassandra_large_mean_current_memory_5,␣
 ↪read_cassandra_large_mean_current_memory_5,
```

```
                                update_cassandra_large_mean_current_memory_5,␣
 ↪delete_cassandra_large_mean_current_memory_5]
mean_current_with_index = [create_cassandra_large_mean_current_memory_5_index,␣
 ↪read_cassandra_large_mean_current_memory_5_index,
                           update_cassandra_large_mean_current_memory_5_index,␣
 ↪delete_cassandra_large_mean_current_memory_5_index]
std_current_without_index = [create_cassandra_large_std_current_memory_5,␣
 ↪read_cassandra_large_std_current_memory_5,
                             update_cassandra_large_std_current_memory_5,␣
 ↪delete_cassandra_large_std_current_memory_5]
std_current_with_index = [create_cassandra_large_std_current_memory_5_index,␣
 ↪read_cassandra_large_std_current_memory_5_index,
                          update_cassandra_large_std_current_memory_5_index,␣
 ↪delete_cassandra_large_std_current_memory_5_index]

mean_peak_without_index = [create_cassandra_large_mean_peak_memory_5,␣
 ↪read_cassandra_large_mean_peak_memory_5,
                           update_cassandra_large_mean_peak_memory_5,␣
 ↪delete_cassandra_large_mean_peak_memory_5]
mean_peak_with_index =  [create_cassandra_large_mean_peak_memory_5_index,␣
 ↪read_cassandra_large_mean_peak_memory_5_index,
                           update_cassandra_large_mean_peak_memory_5_index,␣
 ↪delete_cassandra_large_mean_peak_memory_5_index]
std_peak_without_index = [create_cassandra_large_std_peak_memory_5,␣
 ↪read_cassandra_large_std_peak_memory_5,
                          update_cassandra_large_std_peak_memory_5,␣
 ↪delete_cassandra_large_std_peak_memory_5]
std_peak_with_index = [create_cassandra_large_std_peak_memory_5_index,␣
 ↪read_cassandra_large_std_peak_memory_5_index,
                          update_cassandra_large_std_peak_memory_5_index,␣
 ↪delete_cassandra_large_std_peak_memory_5_index]

fig, axes = plt.subplots(4, 1, figsize=(12, 8))
width = 0.8

for i, action in enumerate(actions):
    ax = axes[i]
    x = np.arange(4)  # 4 barres par graphique : Mem actuelle sans index, Mem␣
 ↪actuelle avec index, Mem de pointe sans index, Mem de pointe avec index
    mean_values = [mean_current_without_index[i], mean_current_with_index[i],␣
 ↪mean_peak_without_index[i], mean_peak_with_index[i]]
    std_values = [std_current_without_index[i], std_current_with_index[i],␣
 ↪std_peak_without_index[i], std_peak_with_index[i]]
```

```
    bars_current_without = ax.barh(x[0] - width, mean_values[0], width,␣
↪xerr=std_values[0], label='Mémoire actuelle sans index', capsize=5,␣
↪color='tab:orange')
    bars_current_with = ax.barh(x[1], mean_values[1], width,␣
↪xerr=std_values[1], label='Mémoire actuelle avec index', capsize=5,␣
↪color='#FFD590')
    bars_peak_without = ax.barh(x[2] + width, mean_values[2], width,␣
↪xerr=std_values[2], label='Mémoire de pointe sans index', capsize=5,␣
↪color='tab:blue')
    bars_peak_with = ax.barh(x[3] + 2 * width, mean_values[3], width,␣
↪xerr=std_values[3], label='Mémoire de pointe avec index', capsize=5,␣
↪color='#89CFF0')

    ax.set_xlabel('Mémoire (en Mo)')
    ax.set_ylabel('Type de mémoire et indexation')
    ax.set_title(f'Comparaison de la mémoire pour {action} (Cassandra 5␣
↪réplicats)')
    ax.set_yticks(x)
    ax.legend()

    def add_values(bars):
        for bar in bars:
            xval = bar.get_width()
            ax.text(xval, bar.get_y() + bar.get_height() / 2, f'{xval:.2f}',␣
↪va='center', ha='left')

    add_values(bars_current_without)
    add_values(bars_current_with)
    add_values(bars_peak_without)
    add_values(bars_peak_with)

plt.tight_layout()
plt.show()
```



Pour SQLite, l'utilisation d'un index n'a pas montré de réelle différence sur l'opération CREATE. En revanche, elle a considérablement amélioré les performances des autres opérations : un gain de vitesse de 4x pour READ, une division par 8 pour UPDATE, et par 9 (ou 10) pour DELETE.

Pour Cassandra, l'impact de l'index est plus nuancé. Aucune différence notable n'a été observée sur CREATE, mais les gains sont significatifs pour les autres opérations : READ est 5 fois plus rapide, tandis que UPDATE et DELETE sont 2 fois plus rapides. Ces constats restent valables pour les configurations avec 2 ou 5 réplicas.

Enfin, en termes de mémoire, l'ajout d'un index ou la modification du nombre de réplicas n'a eu aucun impact, que ce soit pour SQLite ou Cassandra.

5 Fin du notebook

[55]:
```
# fermer proprement
session.shutdown() # Fermer la connexion Cassandra
cluster.shutdown() # Fermer le cluster Cassandra
conn.close() # Fermer la connexion SQLite
```

6 Conclusion

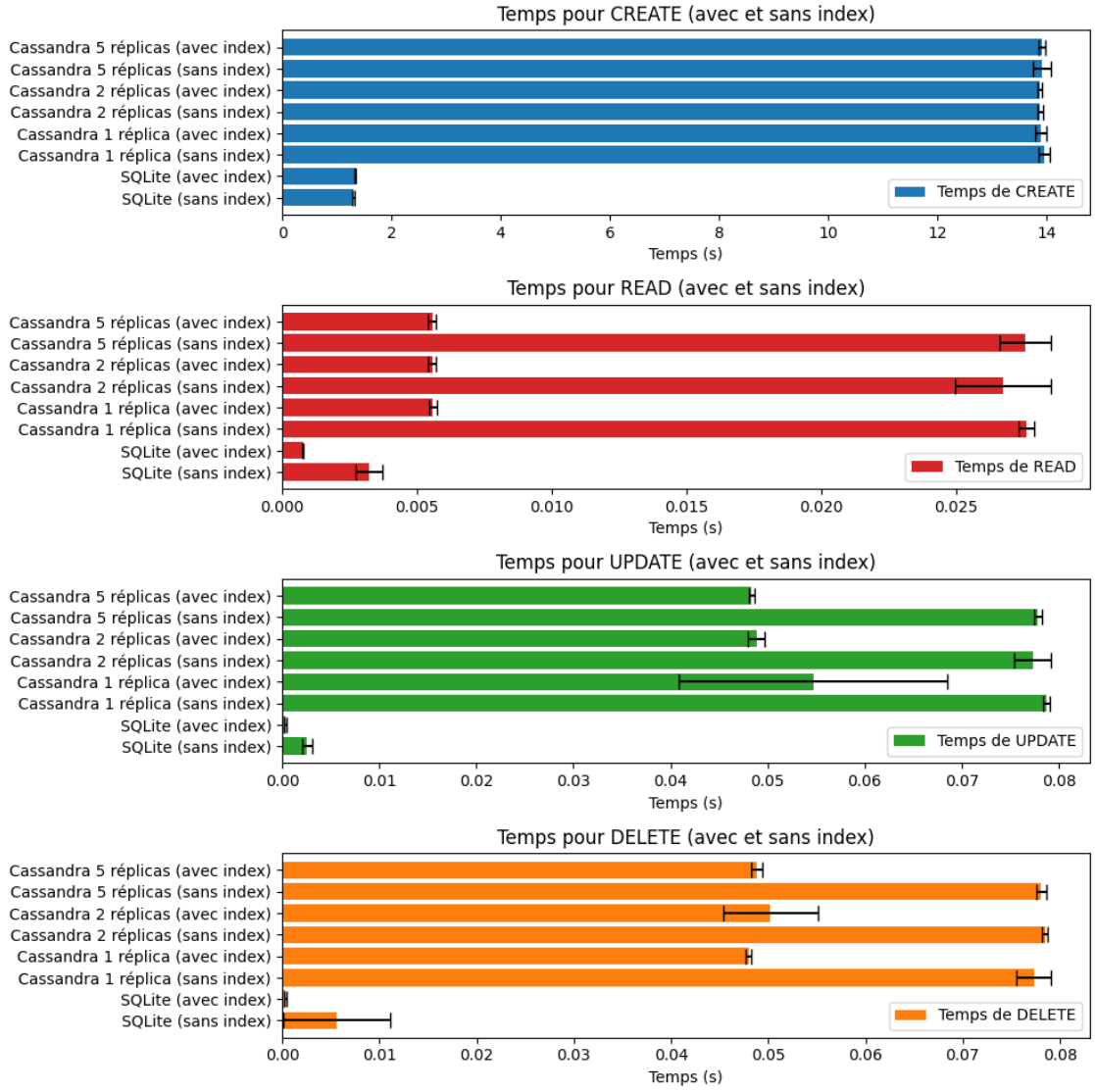
[56]:
```
sqlite_times = {
    'CREATE': (create_sqlite_large_mean_time, create_sqlite_large_std_time),
    'READ': (read_sqlite_large_mean_time, read_sqlite_large_std_time),
    'UPDATE': (update_sqlite_large_mean_time, update_sqlite_large_std_time),
    'DELETE': (delete_sqlite_large_mean_time, delete_sqlite_large_std_time)
}

sqlite_times_with_index = {
    'CREATE': (create_sqlite_large_mean_time_index,␣
 ↪create_sqlite_large_std_time_index),
    'READ': (read_sqlite_large_mean_time_index,␣
 ↪read_sqlite_large_std_time_index),
    'UPDATE': (update_sqlite_large_mean_time_index,␣
 ↪update_sqlite_large_std_time_index),
    'DELETE': (delete_sqlite_large_mean_time_index,␣
 ↪delete_sqlite_large_std_time_index)
}

cassandra_1_replicas_times = {
    'CREATE': (create_cassandra_large_mean_time,␣
 ↪create_cassandra_large_std_time),
    'READ': (read_cassandra_large_mean_time, read_cassandra_large_std_time),
    'UPDATE': (update_cassandra_large_mean_time,␣
 ↪update_cassandra_large_std_time),
    'DELETE': (delete_cassandra_large_mean_time,␣
 ↪delete_cassandra_large_std_time)
}

cassandra_1_replicas_times_index = {
    'CREATE': (create_cassandra_large_mean_time_index,␣
 ↪create_cassandra_large_std_time_index),
    'READ': (read_cassandra_large_mean_time_index,␣
 ↪read_cassandra_large_std_time_index),
    'UPDATE': (update_cassandra_large_mean_time_index,␣
 ↪update_cassandra_large_std_time_index),
    'DELETE': (delete_cassandra_large_mean_time_index,␣
 ↪delete_cassandra_large_std_time_index)
}

cassandra_2_replicas_times = {
    'CREATE': (create_cassandra_large_mean_time_2,␣
 ↪create_cassandra_large_std_time_2),
    'READ': (read_cassandra_large_mean_time_2, read_cassandra_large_std_time_2),
```

```
    'UPDATE': (update_cassandra_large_mean_time_2,␣
 ↪update_cassandra_large_std_time_2),
    'DELETE': (delete_cassandra_large_mean_time_2,␣
 ↪delete_cassandra_large_std_time_2)
}

cassandra_2_replicas_times_index = {
    'CREATE': (create_cassandra_large_mean_time_2_index,␣
 ↪create_cassandra_large_std_time_2_index),
    'READ': (read_cassandra_large_mean_time_2_index,␣
 ↪read_cassandra_large_std_time_2_index),
    'UPDATE': (update_cassandra_large_mean_time_2_index,␣
 ↪update_cassandra_large_std_time_2_index),
    'DELETE': (delete_cassandra_large_mean_time_2_index,␣
 ↪delete_cassandra_large_std_time_2_index)
}


cassandra_5_replicas_times = {
    'CREATE': (create_cassandra_large_mean_time_5,␣
 ↪create_cassandra_large_std_time_5),
    'READ': (read_cassandra_large_mean_time_5, read_cassandra_large_std_time_5),
    'UPDATE': (update_cassandra_large_mean_time_5,␣
 ↪update_cassandra_large_std_time_5),
    'DELETE': (delete_cassandra_large_mean_time_5,␣
 ↪delete_cassandra_large_std_time_5)
}

cassandra_5_replicas_times_index = {
    'CREATE': (create_cassandra_large_mean_time_5_index,␣
 ↪create_cassandra_large_std_time_5_index),
    'READ': (read_cassandra_large_mean_time_5_index,␣
 ↪read_cassandra_large_std_time_5_index),
    'UPDATE': (update_cassandra_large_mean_time_5_index,␣
 ↪update_cassandra_large_std_time_5_index),
    'DELETE': (delete_cassandra_large_mean_time_5_index,␣
 ↪delete_cassandra_large_std_time_5_index)
}


# Définir les couleurs pour chaque base de données et avec/sans index
colors = ['tab:blue', 'tab:red', 'tab:green', 'tab:orange']

# Créer les sous-graphes
fig, axes = plt.subplots(4, 1, figsize=(10, 10))
```

```
# 1. Graphique CREATE - Tous ensemble
axes[0].barh(['SQLite (sans index)', 'SQLite (avec index)', 'Cassandra 1␣
 ↪réplica (sans index)',
              'Cassandra 1 réplica (avec index)', 'Cassandra 2 réplicas (sans␣
 ↪index)',
              'Cassandra 2 réplicas (avec index)', 'Cassandra 5 réplicas (sans␣
 ↪index)',
              'Cassandra 5 réplicas (avec index)'],
             [sqlite_times['CREATE'][0], sqlite_times_with_index['CREATE'][0],
              cassandra_1_replicas_times['CREATE'][0],␣
 ↪cassandra_1_replicas_times_index['CREATE'][0],
              cassandra_2_replicas_times['CREATE'][0],␣
 ↪cassandra_2_replicas_times_index['CREATE'][0],
              cassandra_5_replicas_times['CREATE'][0],␣
 ↪cassandra_5_replicas_times_index['CREATE'][0]],
             xerr=[sqlite_times['CREATE'][1],␣
 ↪sqlite_times_with_index['CREATE'][1],
                   cassandra_1_replicas_times['CREATE'][1],␣
 ↪cassandra_1_replicas_times_index['CREATE'][1],
                   cassandra_2_replicas_times['CREATE'][1],␣
 ↪cassandra_2_replicas_times_index['CREATE'][1],
                   cassandra_5_replicas_times['CREATE'][1],␣
 ↪cassandra_5_replicas_times_index['CREATE'][1]],
             label='Temps de CREATE', color=colors[0], capsize=5)

axes[0].set_title('Temps pour CREATE (avec et sans index)')
axes[0].set_xlabel('Temps (s)')
axes[0].legend()

# 2. Graphique READ - Par base de données
axes[1].barh(['SQLite (sans index)', 'SQLite (avec index)', 'Cassandra 1␣
 ↪réplica (sans index)',
              'Cassandra 1 réplica (avec index)', 'Cassandra 2 réplicas (sans␣
 ↪index)',
              'Cassandra 2 réplicas (avec index)', 'Cassandra 5 réplicas (sans␣
 ↪index)',
              'Cassandra 5 réplicas (avec index)'],
             [sqlite_times['READ'][0], sqlite_times_with_index['READ'][0],
              cassandra_1_replicas_times['READ'][0],␣
 ↪cassandra_1_replicas_times_index['READ'][0],
              cassandra_2_replicas_times['READ'][0],␣
 ↪cassandra_2_replicas_times_index['READ'][0],
              cassandra_5_replicas_times['READ'][0],␣
 ↪cassandra_5_replicas_times_index['READ'][0]],
             xerr=[sqlite_times['READ'][1], sqlite_times_with_index['READ'][1],
```

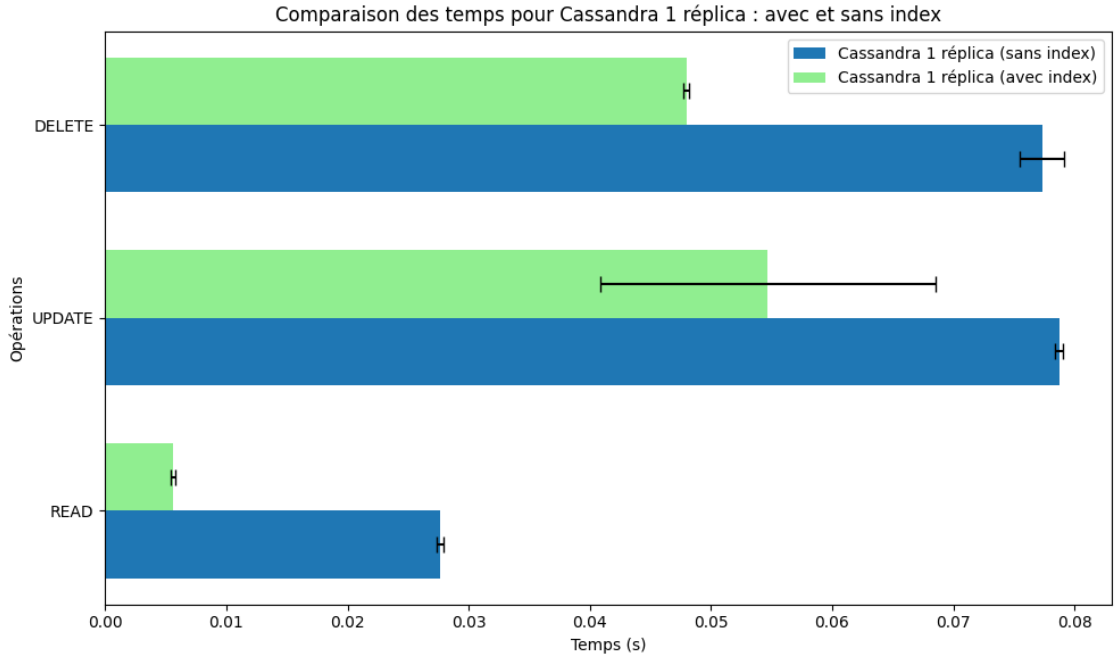
```
                    cassandra_1_replicas_times['READ'][1],␣
 ↪cassandra_1_replicas_times_index['READ'][1],
                    cassandra_2_replicas_times['READ'][1],␣
 ↪cassandra_2_replicas_times_index['READ'][1],
                    cassandra_5_replicas_times['READ'][1],␣
 ↪cassandra_5_replicas_times_index['READ'][1]],
             label='Temps de READ', color=colors[1], capsize=5)

axes[1].set_title('Temps pour READ (avec et sans index)')
axes[1].set_xlabel('Temps (s)')
axes[1].legend()

# 3. Graphique UPDATE - Par base de données
axes[2].barh(['SQLite (sans index)', 'SQLite (avec index)', 'Cassandra 1␣
 ↪réplica (sans index)',
              'Cassandra 1 réplica (avec index)', 'Cassandra 2 réplicas (sans␣
 ↪index)',
              'Cassandra 2 réplicas (avec index)', 'Cassandra 5 réplicas (sans␣
 ↪index)',
              'Cassandra 5 réplicas (avec index)'],
             [sqlite_times['UPDATE'][0], sqlite_times_with_index['UPDATE'][0],
              cassandra_1_replicas_times['UPDATE'][0],␣
 ↪cassandra_1_replicas_times_index['UPDATE'][0],
              cassandra_2_replicas_times['UPDATE'][0],␣
 ↪cassandra_2_replicas_times_index['UPDATE'][0],
              cassandra_5_replicas_times['UPDATE'][0],␣
 ↪cassandra_5_replicas_times_index['UPDATE'][0]],
             xerr=[sqlite_times['UPDATE'][1],␣
 ↪sqlite_times_with_index['UPDATE'][1],
                    cassandra_1_replicas_times['UPDATE'][1],␣
 ↪cassandra_1_replicas_times_index['UPDATE'][1],
                    cassandra_2_replicas_times['UPDATE'][1],␣
 ↪cassandra_2_replicas_times_index['UPDATE'][1],
                    cassandra_5_replicas_times['UPDATE'][1],␣
 ↪cassandra_5_replicas_times_index['UPDATE'][1]],
             label='Temps de UPDATE', color=colors[2], capsize=5)

axes[2].set_title('Temps pour UPDATE (avec et sans index)')
axes[2].set_xlabel('Temps (s)')
axes[2].legend()

# 4. Graphique DELETE - Par base de données
axes[3].barh(['SQLite (sans index)', 'SQLite (avec index)', 'Cassandra 1␣
 ↪réplica (sans index)',
              'Cassandra 1 réplica (avec index)', 'Cassandra 2 réplicas (sans␣
 ↪index)',
```

```
             'Cassandra 2 réplicas (avec index)', 'Cassandra 5 réplicas (sans␣
 ↪index)',
             'Cassandra 5 réplicas (avec index)'],
            [sqlite_times['DELETE'][0], sqlite_times_with_index['DELETE'][0],
             cassandra_1_replicas_times['DELETE'][0],␣
 ↪cassandra_1_replicas_times_index['DELETE'][0],
             cassandra_2_replicas_times['DELETE'][0],␣
 ↪cassandra_2_replicas_times_index['DELETE'][0],
             cassandra_5_replicas_times['DELETE'][0],␣
 ↪cassandra_5_replicas_times_index['DELETE'][0]],
            xerr=[sqlite_times['DELETE'][1],␣
 ↪sqlite_times_with_index['DELETE'][1],
                  cassandra_1_replicas_times['DELETE'][1],␣
 ↪cassandra_1_replicas_times_index['DELETE'][1],
                  cassandra_2_replicas_times['DELETE'][1],␣
 ↪cassandra_2_replicas_times_index['DELETE'][1],
                  cassandra_5_replicas_times['DELETE'][1],␣
 ↪cassandra_5_replicas_times_index['DELETE'][1]],
            label='Temps de DELETE', color=colors[3], capsize=5)

axes[3].set_title('Temps pour DELETE (avec et sans index)')
axes[3].set_xlabel('Temps (s)')
axes[3].legend()

plt.tight_layout()

plt.show()
```



[57]:
```
operations = ['READ', 'UPDATE', 'DELETE']

width = 0.35
y = np.arange(len(operations))

fig, ax = plt.subplots(figsize=(10, 6))
# Barres pour Cassandra 1 réplica sans index
ax.barh(y - width/2, [cassandra_1_replicas_times[op][0] for op in operations],
        width, label='Cassandra 1 réplica (sans index)', color='tab:blue',
        xerr=[cassandra_1_replicas_times[op][1] for op in operations],␣
 ↪capsize=5)
```

```
# Barres pour Cassandra 1 réplica avec index
ax.barh(y + width/2, [cassandra_1_replicas_times_index[op][0] for op in␣
 ↪operations],
        width, label='Cassandra 1 réplica (avec index)', color='#90EE90',
        xerr=[cassandra_1_replicas_times_index[op][1] for op in operations],␣
 ↪capsize=5)

ax.set_ylabel('Opérations')
ax.set_xlabel('Temps (s)')
ax.set_title('Comparaison des temps pour Cassandra 1 réplica : avec et sans␣
 ↪index')
ax.set_yticks(y)
ax.set_yticklabels(operations)
ax.legend()

plt.tight_layout()
plt.show()
```



De manière générale, CREATE est beaucoup plus rapide avec SQLite qu'avec Cassandra.

Pour READ, SQLite sans index est légèrement plus rapide que Cassandra avec index, tandis que SQLite avec index est nettement plus performant. À l'inverse, Cassandra sans index est significativement plus lent.

Le nombre de réplicas (1, 2, ou 5) n'a eu aucun impact notable sur les performances pour Cassandra.

Pour UPDATE et DELETE, SQLite est extrêmement rapide, surtout avec un index, où les temps

d'exécution sont encore réduits. Cassandra est bien plus lent pour ces deux opérations, mais l'ajout d'un index divise les temps par deux. Cette différence s'explique par le fonctionnement interne de Cassandra : pour effectuer un UPDATE ou un DELETE, il est nécessaire de spécifier la clé primaire complète (partition key + clustering key). Il n'est pas possible de mettre à jour des lignes selon des critères de recherche arbitraires, sauf si ces critères correspondent exactement à la clé primaire. Cela a entrainé des opérations supplémentaires : un SELECT préalable.

Enfin, CREATE reste globalement l'opération la plus longue. Cassandra offre des performances compétitives pour READ avec index.

Sur la mémoire, les métriques current et peak offrent des indications importantes :

- Current correspond à la quantité de mémoire utilisée par l'application au moment de la mesure.
- Peak correspond au maximum de mémoire utilisée durant l'exécution, ce qui reflète les besoins en ressources dans les scénarios les plus intensifs. Dans nos tests, aucune variation notable n'a été observée pour current et peak entre les différentes configurations de réplicas ou l'utilisation d'un index, que ce soit pour SQLite ou Cassandra. Cependant, nous avons remarqué que pour CREATE, la consommation peak de SQLite est similaire à celle de Cassandra, ce qui indique un usage mémoire comparable pour cette opération.

6.0.1 Résultats

Dans cette étude, plusieurs tests ont été réalisés pour comparer les performances entre SQLite et Cassandra. Les tests ont été conçus de manière simple, avec une mise en place méthodologique d'un benchmark. Chaque opération a été répétée cinq fois pour obtenir des moyennes et écarts-types (mean et std), en utilisant des requêtes cohérentes pour garantir la comparabilité des résultats. Le processus comprenait le DROP de toutes les données, suivi d'un CREATE systématique (et éventuellement d'un SELECT, UPDATE, ou DELETE selon l'opération testée), ce qui explique la longueur des éxécutions.

En termes de vitesse, CREATE s'est avéré être l'opération la plus lente pour tous les systèmes testés. En revanche, READ était nettement plus rapide que les autres requêtes dans Cassandra. De manière générale, SQLite s'est montré plus rapide pour toutes les opérations, ce qui s'explique par son fonctionnement local et non distribué, contrairement à Cassandra. Toutefois, cette configuration distribuée n'a pas pu être pleinement testée avec nos ressources matérielles limitées.

Concernant l'ajout de réplicas, aucune différence significative n'a été observée sur les performances. Même constat avec un dataset plus grand (8 800 données et 30 000 entrées) : les différences de temps d'exécution sont restés similaires, bien que l'exécution de ce type de tests sur un dataset encore plus grand aurait été trop exigeante pour notre environnement actuel (le notebook est déjà très long à cause du benchmark).

L'utilisation d'un index a apporté une amélioration nette des temps d'exécution, tant pour SQLite que pour Cassandra, réduisant considérablement les durées pour READ, UPDATE et DELETE.

Quelques limitations ont été relevées :

- Le besoin d'utiliser l'option `ALLOW FILTERING` pour Cassandra lors des tests sans clé primaire complète s'est avéré contraignant, imposant des critères d'égalité peu flexibles.

- Les opérations UPDATE et DELETE dans Cassandra nécessitent souvent une étape préalable de SELECT, même lorsqu'un index ou une clé secondaire est utilisé. Cette contrainte, inhérente au fonctionnement de Cassandra, peut introduire un biais dans les comparaisons, car les modifications finales ne sont effectuées que sur la clé primaire complète (partition key + clustering key). Nous avons tenté d'ajouter un champ supplémentaire, comme release year, dans la clé primaire (à la fois comme partition key et comme clustering key). Cependant, cette approche s'est révélée peu concluante :
  - Soit il fallait activer ALLOW FILTERING, ce qui est inefficace et fortement déconseillé dans un contexte de production.
  - Soit il était nécessaire de réaliser un SELECT préalable pour identifier précisément les lignes à mettre à jour ou supprimer, ce qui alourdit les opérations d'UPDATE et de DELETE.